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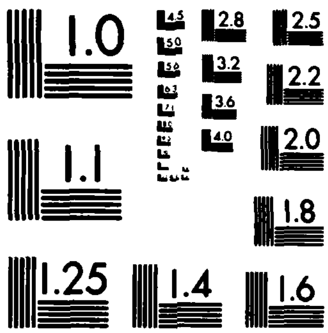

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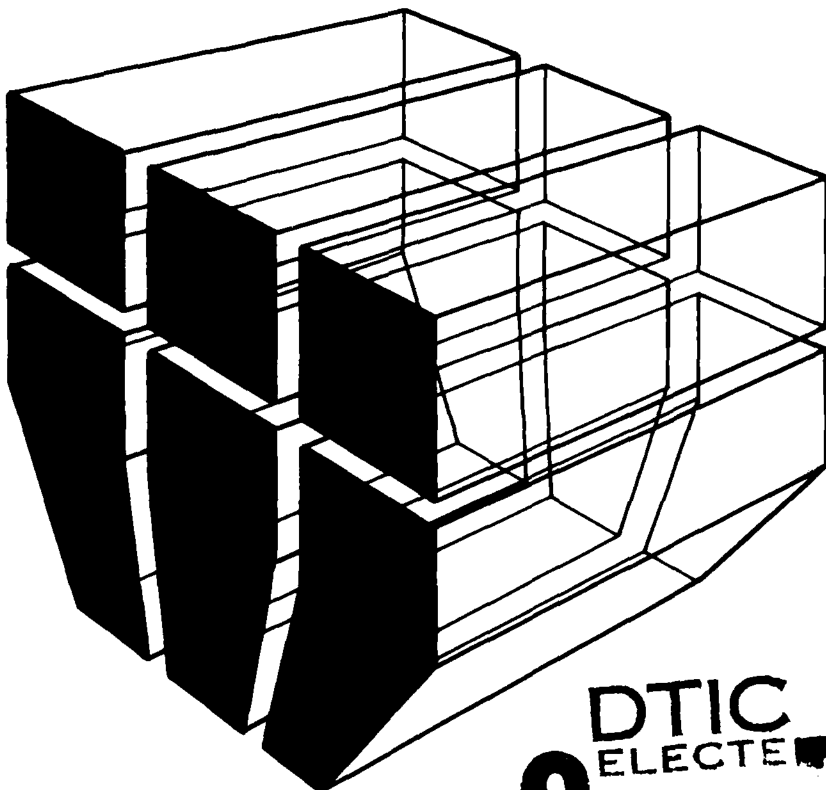
US Army Corps
of Engineers
Construction Engineering
Research Laboratory

TECHNICAL REPORT N-85/07
February 1985

AD-A153 140

A SURVEY OF WATER DEMAND FORECASTING PROCEDURES ON FIXED ARMY INSTALLATIONS



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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER CERL-TR-N-85/07	2. GOVT ACCESSION NO. AD A153 140	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A SURVEY OF WATER DEMAND FORECASTING PROCEDURES ON FIXED ARMY INSTALLATIONS		5. TYPE OF REPORT & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) LTC J. F. Langowski, J. T. Bandy, L. E. Lang, E. D. Smith		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. ARMY CONSTRUCTION ENGINEERING RESEARCH LABORATORY P.O. BOX 4005, CHAMPAIGN, IL 61820		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 4A162720A896-A-031
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE February 1985
		13. NUMBER OF PAGES 102
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Copies are available from the National Technical Information Service
Springfield, VA 22161

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

water resources
water demand
water conservation
forecasting

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A recent National Defense Institute (NDI) study determined that 93 percent of the Army's installations are in hydrologic areas which have recurring problems of insufficient quantity and decreasing quality of water. This report documents research conducted by the U.S. Army Construction Engineering Research Laboratory to (1) determine the nature and type of water planning and management activities practiced by installation water utility managers, (2) evaluate current Army procedures for estimating average daily water demand,

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(3) formulate a procedure to determine which Army installations should be considered for a water use survey, and (4) determine the adequacy of contingency plans required by Army regulations.

Current guidelines and procedures for estimating daily average water demand were reviewed and 90 installations were surveyed to determine water service patterns and management practices, including water costs, conservation programs, and contingency plans. Sectors of water installation use as a function of building area were determined. These relationships were used to test and evaluate a linear additive model.

It was found that current procedures for estimating water demand contain major discrepancies. Improved water planning guidelines are needed to help predict water demand, formulate water shortage contingency plans, and assess potential water conservation techniques. The survey results indicated that about one third of the respondents needed better tools to estimate future water demand. Most respondents did not have formal contingency plans or water conservation programs. The linear additive model uses categorized building areas (data readily available to installation Facility Engineers) to predict water use sectors. Testing of the model showed that it could effectively predict peacetime water use and be used to evaluate the effectiveness of conservation measures.

FOREWORD

This research was conducted for the Assistant Chief of Engineers under Project 4A162720A896, "Environmental Quality Technology"; Technical Area A, "Installation Environmental Management Strategy"; Work Unit 031, "Closed Loop Water Conservation/Supply Augmentation Techniques." The applicable QCR is 6.27.20A. The OCE Technical Monitor was Mr. R. Newsome, DAEN-ZCF-U.

This work is based on Dr. John Langowski's doctoral research at Southern Illinois University under the direction of Dr. Duane Baumann. This research was directed by the Environmental (EN) Division, U.S. Army Construction Engineering Research Laboratory (USA-CERL). Appreciation is extended to Ms. Martha Blake (USA-CERL) and to members of Dr. Langowski's dissertation committee.

Dr. R. K. Jain is Chief of USA-CERL-EN. COL Paul J. Theuer is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director.

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1 INTRODUCTION

Background

A recent National Defense Institute (NDI) study[1] determined that 93 percent of the Army's installations are in hydrologic areas that have recurring problems of insufficient quantity and decreasing quality of water. Planning for future water requirements on U. S. Army installations has recently received new emphasis, stimulated by national assessments of water resources availability, competition for water's myriad uses, and increasing costs of development, treatment, and distribution. New reservoir sites are scarce and groundwater resources have been fully exploited in many areas. Production costs related to water service are increasing due to higher costs for energy and for treatment technologies that comply with mandated water quality standards. These new, complex problems require installation water planners to review current planning guidelines and existing methods for estimating the water needs of soldiers, their families, and civilians who reside or work on Army posts within the contiguous United States.

In general, historical installation water service planning has focused on engineering design to determine the appropriate size of initial system configurations or the extent to which system components should be expanded when existing capacities or capabilities are overtaxed. Army technical manuals which provide water supply planning guidance to installation facility engineers are being reviewed, and it is essential that modifications incorporate improved water supply and demand management planning procedures. Such procedures should be commensurate with approved and proven techniques that can prevent premature investment or hasten overdue expenditures of defense dollars in water utility expansion.

Objective

The objectives of this study were to: (1) determine the nature and type of water planning being practiced by installation water utility managers; (2) evaluate current Army procedures for estimating average daily water demand;

[1] R. D. Schwartz, Current and Projected Water Resources Problems and Their Impact on DOD Installations (Research Directorate, National Defense University, 1979).

(3) formulate a procedure for determining which installations should be considered for a water use survey; and (4) determine the extent and adequacy of contingency plans required by Army regulations.

Approach

A literature search of military and civilian documents related to water supply planning and forecasting was conducted. Thirteen installations were visited and additional information obtained from installation utility managers, water treatment plant supervisors, and master planners. A mail survey was also made of 93 installations to obtain information relevant to the NDI assessment. Chapter 2 outlines the details of these activities.

Current guidelines and procedures for estimating average daily water demand prescribed by Army technical manuals were evaluated and predictive ability was demonstrated, using empirical installation data. Water service patterns and water management practices at 90 Army installations were surveyed (Chapter 3).

Distinct sectors of installation water use were determined as a function of allocated building area gross square footage (Chapter 4); a conceptualized linear additive model was then developed that related these sectors to average daily water use and the regression results interpreted (Chapter 5).

Scope

This study is limited to fixed Army installations in the contiguous United States and to the water service and water planning procedures and guidelines available to and practiced by them. The model presented in Chapter 5 is for information only; it is not for use in official project or programming authorization documents.

Mode of Technology Transfer

The information in this report will provide the basis for an Engineer Technical Note. It may also impact Technical Manual 5-813-1, Water Supply Sources and General Considerations (1979).

2 DATA SOURCES AND RESEARCH DESIGN

The Role of Conservation in Water Supply Planning

The NDI study determined that conservation is a primary method for alleviating water shortages. The Corps' Institute for Water Resources contends that evaluation of water conservation measures must be based on and facilitated by a disaggregated forecast of water requirements that predicts the unrestricted use of water.[2] Baumann[3] clearly indicates that estimating the effectiveness of a water conservation measure is a function of its effects on specific types of sectoral water use.

To measure beneficial reductions in water uses and losses, the unrestricted quantity of water used by appropriate sectors must be known in advance. For example, unless a reasonable estimate can be made of current water use in family housing and bachelor soldier quarters, the effects of installing low-flow shower heads in these buildings cannot be predicted. The expected effectiveness with the "residential" sector in terms of water reduction quantities and customer acceptability must be known. This is the major dilemma of water conservation planning for military installations. Water use by sectors corresponding to the conventional classification of residential, commercial, and industrial water use is currently unassessed and is not used to estimate water needs at Army posts.

Historical average daily water use on Army installations has been computed based on an effective population, adjusted by a sizing capacity factor, and multiplied by a peacetime daily per capita use of 150 gal.* There is no discrimination among categories of water usages and supposedly very limited meter data to permit differentiation. The U.S. Army Construction Engineering Research Laboratory (USA-CERL) recently conducted a study to determine proportions of water consumed, by major category, at Fort Bliss, TX, Fort Bragg, NC, Fort Lewis, WA, and Fort Carson, CO.[4] They concluded that the largest users of water on these fixed installations were troop and family housing and landscape irrigation. Industrial water use, especially tactical vehicle washing, was also a major component. The four selected installations were expected to differ in certain sectoral water uses and the findings verified this hypothesis, but without an explicit comparison to reveal reasons for differences

[2] J. E. Crews and D. D. Baumann, "Choosing the Appropriate Forecasting Technique," a paper presented at American Water Resources Association, Illinois Section Conference, Carbondale, Illinois (April 4-7, 1984).
[3] D. D. Baumann, J. J. Boland, and J. H. Sims, The Evaluation of Water Conservation for Municipal and Industrial Water Supply Procedures Manual, Report No. 80-1 (Institute for Water Resources, U.S. Army Corps of Engineers, 1980).
[4] J. T. Bandy and R. J. Scholze, Distribution of Water Use at Representative Fixed Army Installations, Technical Report N-157/A133232 (U.S. Army Construction Engineering Research Laboratory [USA-CERL], 1982).
*1 gal = 3.785 L.

or similarities. USA-CERL is conducting an ongoing study to address this problem by installing meters at selected points in the distribution system at Fort Bragg.

Ideally, metered data or billing information would provide a database to accurately assess existing water use patterns and measure water use quantities by sector. However, this type of database is rare or nonexistent, because water is not priced and rarely metered on Army installations. This limits the method of forecasting future water service to a per capita approach, based on average daily water delivery. Moreover, this approach as well as its accompanying guidelines that prescribe procedures for estimating average daily water demand are inadequate, and an improved method is needed to improve water supply planning at Army installations. This includes information gathered from existing databases or by generating new data and broadening the information pertinent to these issues. Very little aggregated information is currently on hand, and Army water resource managers need information from individual installations to determine the status of their water supply planning. Thus, an inventory of water supply planning activities is clearly warranted.

Water Service for Army Installations and Civilian Communities: A Comparison

Army installations in the contiguous United States resemble small civilian communities, ranging in population from 100 to 70,000 people. Figure 1 summarizes the flow of water through an Army installation and shows the Army Technical Manuals applicable to each stage. There is some similarity in the water utility management infrastructure in that the typical civilian community Director of Public Works, assisted by a planning and engineering staff and by water treatment plant personnel, is mirrored by the Director of Engineering and Housing (DEH) and a commensurate support workforce on an Army installation. In this example, both are under the domain of government ownership. There are no privately owned water utilities within a military installation, although water may be purchased from a nearby public or private utility for installation needs. Water for either type of community may be obtained directly from surface or ground water sources or purchased from wholesalers. Operation and maintenance costs are parallel between both entities; however, these costs, as well as capital expenditures for military installations, are appropriated and programmed as part of the Department of Defense budget. Both civilian and military communities follow water quality standards promulgated by Federal or State regulatory agencies. Also, it has already been suggested that water-using activities on an Army installation may be aligned with commonly recognized sectors of water use: residential, commercial, industrial, and institutional. These likenesses between Army installations and civilian communities imply that advancement in water planning methods, particularly water requirement forecasting techniques, are equally applicable and appropriate for consideration by both parties. This last point was used as an initial assumption in gathering information relevant to this study; accordingly, it

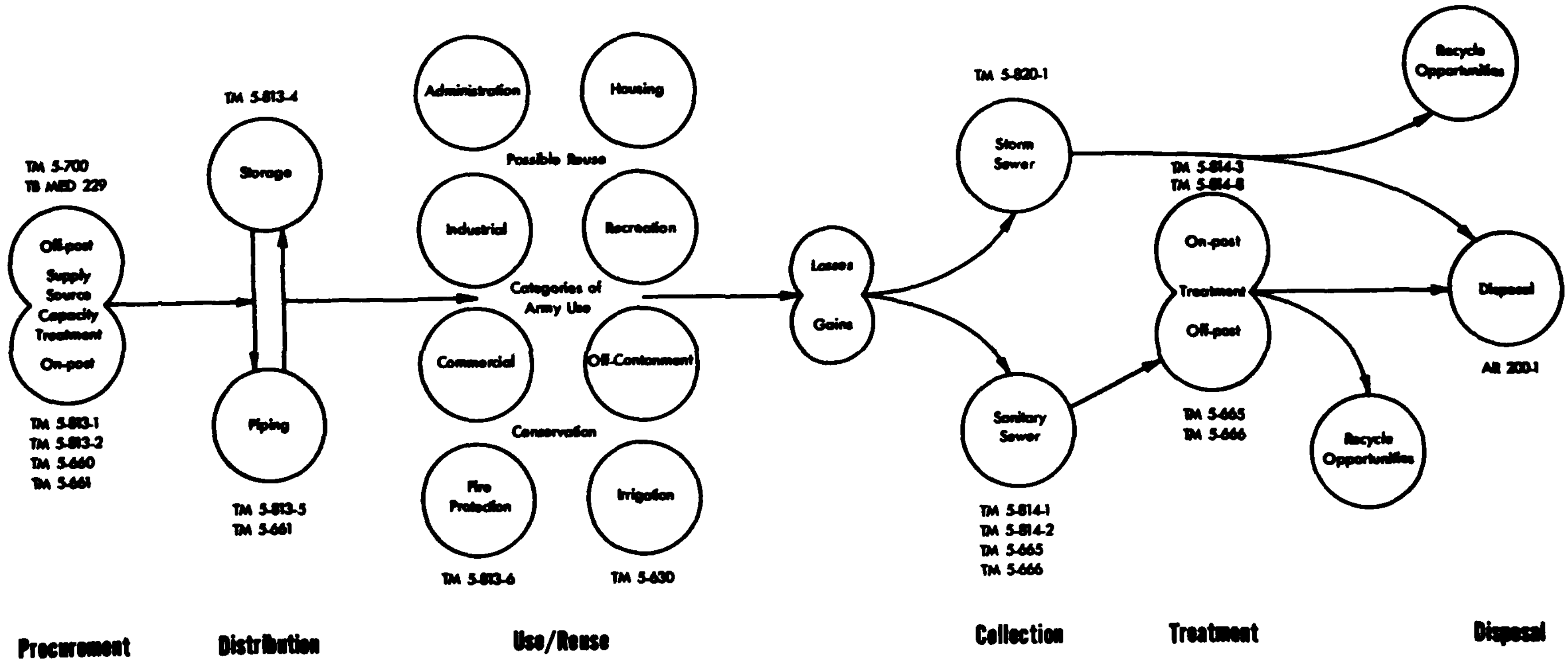

Figure 1. Flow of water and typical water used at fixed Army installations.

has stimulated a literature review to determine the scope, content, and results of studies related to water demand forecasting. Despite strong similarities, there are special considerations that must be given to the nature of installation water use which indicate some difference when compared to sister civilian communities. Scholze[5] has indicated that:

1. Total service population fluctuates daily because of large numbers of civilian employees who reside off-post and commute daily to their jobs on the post. The number of consumers also varies with soldier maneuvers and training exercises conducted within and beyond installation boundaries. The impact can range from hundreds to thousands of Reserve or Army National Guard soldiers arriving for temporary duty during certain periods of the year, causing large surges in normal water service; on the other hand, tenant troop units may deploy for training at sites beyond the installation, causing corresponding reductions in total water quantities.

2. Army personnel pay a fixed amount for unlimited quantities of water through forfeiture of their quarters allowance and are not subject to rate structures. They do not pay directly for the water they use, so with limited exceptions, meters have not been needed.

3. Activities unique to the Army, such as tactical vehicle and aircraft washing and maintenance, affect installation water service and quantity requirements.

4. Army personnel must follow command orders and instructions, implying quick enforcement of directives implementing water conservation measures.

There are other qualifiers that may also relate to water service or water utility record management:

5. Installations are characterized by their military missions: soldier schools and major training centers, logistical production and supply depots, medical centers, or research, development, and testing sites. Some installations are dedicated primarily to one of these missions; however, in most cases, there are activities that represent some aspect of all of these missions, with one or two missions dominating.

6. Installation real property (all buildings and acreage) is Army-owned, being operated and maintained by DEH on behalf of the Installation Commander. Procedurally, the DEH recommends to the Commander actions for improving the efficiency and capability of support on a continuing basis. A Commander's decision to implement the recommendation, such as water conservation measures, is communicated as a directive and if it involves water reduction, plumbing fixtures, or educational programs, the DEH will comply throughout

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[5] R. J. Scholze, L. J. Benson, M. A. Kamiya, M. J. Staub, and J. T. Bandy, Water Conservation Methods for U. S. Army Installations: Volume I, Residential Usage Management, Technical Report N-146/A128550 (USA-CERL, 1982).

the installation. The reciprocal also holds, in that a Commander's decision not to conserve (e.g., limit irrigation of common areas such as parade and athletic fields and other large grassed areas) is also carried out.

7. Installations are designed to support the activities related to their military mission: various training areas, vehicle and aircraft park and maintenance complexes, family and soldier housing, community buildings, and other building categories are surrogate representatives of both the population size and mission activities of the installation. As such, allocated buildings, their sizes, and their numbers symbolize places where people use water and how water is used.

8. Utility conservation in the Army focuses on reducing energy consumption and includes water conservation. For example, low-flow shower heads have been installed on some posts to reduce the energy costs of boilers or water heaters. There is no water conservation policy per se.

9. Periodic water service operation and maintenance reports are submitted from the installation level through the Major Command (MACOM) having jurisdictional authority. The MACOM staff engineer reviews and forwards consolidated reports to the Directorate of Enginering and Construction, Office of The Chief of Engineers. The feeder reports are standardized and well-defined in terms of what is to be reported and how it is to be computed using standard units of measure. Each year, these reports are consolidated, published, and distributed Army-wide to provide commanders and staff officers with an analysis of the Army's real property maintenance activities for the preceding fiscal year (ending September 30). The annual report, commonly referred to as the Redbook, is a valuable source of raw data for analyzing the major facets of facility operation and maintenance. The Directorate of Engineering and Construction also issues technical guidance for installation water utility management in the form of periodic manuals and bulletins.

This last consideration suggests the source of data for water service activities on Army posts. These annual reports were reviewed for this study, and along with other potential sources of information, are discussed below.

Published Sources of Data

The Redbook is divided into seven parts which report costs and operating data for major component activities, such as buildings and grounds, utility operation, and fire prevention protection. Of interest to this study is Part VII, which presents specific water service and system data by installation. The data and related statistics are compiled from Major Command technical data reports, DA Form 2788 series (AR 420-16), and follows the Army management structure classification and reporting requirements (AR 37-100-XX, where XX represents the last two digits of the fiscal year). The Army is in a transitional period between manual preparation of the technical data reports and an automated, interactive, user-oriented management database which will be available by the end of FY 1984. Consequently, Redbooks for FY 1982 and 1983 have not been published, so the Redbook for FY 1981 is the most recent.

Selected data for Fiscal Years 1975 through 1981 were extracted for this study. Prior to 1975, report formats and activity codes differed somewhat; operations and maintenance data were not typical due to installation adjustments in troop support caused by the end of the Vietnam Conflict. This database served as the primary source of data for the water use model developed in Chapter 5.

Ninety separate installations within the contiguous United States are reported in the Fiscal Year 1981 Redbook; these are listed in Table 1, categorized by MACOM. These 90 installations represent the entire population of active Army-owned and -operated fixed posts located within the study area, managed by a Facility Engineer Activity, and subject to the requirements for individually reporting annual Facilities Engineering technical data (DA Form 2788-R). The term "fixed" is used here to mean permanently established installations where water service operation and water system maintenance is managed by a Facility Engineer under the delegated authority of the Installation Commander. This set of installations was surveyed for this study.

Water utility data for each installation are entered in the Redbook as either an operational activity (water service) or a maintenance activity (water system). Water service data include base unit quantities, total costs and unit costs per thousand gallons (k-gal) of water for purchased, surface (filtered), and ground water (unfiltered) operational activities. Water system data relate to treatment, filtration, wells, and distribution maintenance activities, with annual quantities and costs given. Only average daily water use is recorded, and it is shown as total annual water delivered throughout the installation. There is no further disaggregation into seasonal or sectoral water use.

The Redbook also provided data related to population approximations and real property measurements of building gross floor area and improved grounds acreage. This information was required to analyze existing Army water use estimation procedures and to empirically test the conceptualized water use model developed in Chapter 5. Table 2 summarizes the data obtained from the Redbook.

This study has examined categorized total building areas for variance differences in order to sum them into new variables that represent independent sectors of water use. The sectors were subjected to regression analysis to determine their explanatory power. Improved ground acreage and evapotranspiration were also tested. Chapter 5 provides details of this analysis.

Table 1*

Installations Located in the Contiguous United States
(Listed by Major Command)

USA Forces Command (FORSCOM)

Fort Bragg, North Carolina	Fort Meade, Maryland
Fort Campbell, Kentucky	Fort Riley, Kansas
Fort Carson, Colorado	Fort Sheridan, Illinois
Fort Devens, Massachusetts	Fort Stewart, Georgia
Fort Drum, New York	National Training Center California
Fort Hood, Texas	Presidio of San Francisco, California
Fort Indiantown Gap, Pennsylvania	Vancouver Barracks, Washington
Fort Sam Houston, Texas	Yakima Firing Range, Washington
Fort Lawton, Washington	Fort Ord, California
Fort Lewis, Washington	Fort Polk, Louisiana
Fort McCoy, Wisconsin	
Fort McPherson, Georgia	

USA Training and Doctrine Command (TRADOC)

Fort Belvoir, Virginia	Fort Leavenworth, Kansas
Fort Benning, Georgia	Fort Lee, Virginia
Fort Bliss, Texas	Fort McClellan, Alabama
Fort Chaffee, Arizona	Fort Monroe, Virginia
Fort Dix, New Jersey	Fort Hamilton, New York
Fort Eustis, Virginia	Fort Pickett, Virginia
Fort Gordon, Georgia	Fort Rucker, Alabama
Fort Benjamin Harrison, Indiana	Fort Sill, Oklahoma
Fort A. P. Hill, Virginia	Fort Leonard Wood, Missouri
Fort Jackson, South Carolina	Carlisle Barracks, Pennsylvania
Fort Knox, Kentucky	

USA Communications Command (ACC)

Fort Huachuca, Arizona	Fort Ritchie, Maryland

United States Military Academy

United States Military Academy, West Point, New York

*Source: FY 1981 Redbook.

Table 1 (Cont'd)

USA Materiel Command (AMC)

Anniston AD, Alabama
Army Materials and Mechanics Research Center, Massachusetts
Harry Diamond Laboratories, Maryland
Letterkenny AD, Pennsylvania
Lexington-Blue Grass AD, Kentucky
McAlester AAP, Oklahoma
Navajo Depot Activity, Arizona
New Cumberland AD, Pennsylvania
Picatinny Arsenal, New Jersey
Pine Bluff Arsenal, Arkansas
Pueblo Depot Activity, Colorado
Red River Arsenal, Texas
Redstone Arsenal, Alabama
Rock Island Arsenal, Illinois
Rocky Mountain Arsenal, Colorado
Sacramento AD, California
Savanna AD, Illinois
Seneca AD, New York
Sharpe AD, California
Sierra AD, California
Tobyhanna AD, Pennsylvania
Tooele AD, Utah
Umatilla Depot Activity, Oregon
Fort Wingate Depot Activity, New Mexico
Watervliet Arsenal, New York
Corpus Christie AD, Texas
Detroit Arsenal, Michigan
Fort Monmouth, New Jersey
Jefferson Proving Ground, Indiana
St. Louis Area Support Center, Illinois
Aberdeen Proving Ground, Maryland
Dugway Proving Ground, Utah
Natick Development Center, Masachusetts
White Sands Missile Range, New Mexico
Yuma Proving Ground, Arizona

USA Health Services Command (HSC)

Fort Detrick, Maryland
Fitzsimons Army Medical Center, Colorado
Walter Reed Army Medical Center, District of Columbia

USA Intelligence and Security Command (INSCOM)

Arlington Hall Station, Virginia
Vint Hill Farms Station, Virginia

Military Traffic Management Command (MTMC)

Bayonne Military Ocean Terminal, New Jersey
Gulf Outport, Louisiana
Oakland Army Base, California
Sunny Point Military Ocean Terminal, North Carolina

Table 2

Redbook Raw Data Summary

Data Category	Type of Data	Unit of Measure	Description
Water service operation	Total water requirements	k-gallons per year	Total annual water requirements from purchased surface and ground water sources for each installation
	Unit costs	Dollars per k-gallons per year	Unit costs for water service operations disaggregated by source of water only
Water system maintenance and repair	Total costs	Dollars per year	Total annual costs for the maintenance and repair of treatment and filtration equipment, wells, and distribution system
Population	Effective population	Persons	Average daily effective population includes all resident soldiers, families, and a proportion of nonresident civilian and military personnel who work on each installation
Real property	Building gross floor area	k-sq ft	Total square footage of gross floor areas of all buildings aggregated into 12 nonoverlapping functional categories
	Total improved grounds	Acres	Intensively used ground areas where annual requirements for maintenance measures exist, consisting of irrigation, dust control, and others

Table 3 summarizes other sources of data for possible adaptation to the objectives of this study. Those noted as general references were most helpful in identifying points of contact and installation locations not commonly found elsewhere.

Installation Visits

Twelve installations were visited between 5 and 29 January 1984 to conduct informal discussions with the Facility Engineer and/or his/her designated utility manager regarding water service, to obtain associated water supply data and reports, and to tour water treatment plant facilities, when practical. At four installations, the mail survey was pretested before its release to all other installations in the study area. Within time and money constraints, the four installations were selected to represent the Major Commands, principal mission activities, and various geographical regions. Table 4 lists the characteristics of the installations visited. Arrangements for each visit were coordinated in advance with the respective MACOM engineers and each installation DEH. During these visits, discussions were held with 61 planners, utility supervisors, and engineers experienced in the operation and maintenance of the installation water systems.

Mail Survey

To meaningfully characterize water use and water planning experience of installations in the study area, it was necessary to know the extent and content of:

1. Installation water use forecasts and the planning methods employed

2. Documented contingency plans for short-term water shortage events and the kinds of water conservation measures included in the plans

3. Water conservation programs implemented in the recent past.

The Deputy Director for Facilities Engineering and Housing, OCE, and each MACOM engineer were coordinated with before the survey. The survey questionnaire is provided in Appendix A.

The installations surveyed included all 90 in the study area and three others not reported separately in the Redbook, which are consolidated under the Military District of Washington (MWD); although there is no individual historic Redbook data regarding their water service, their response concerning water planning activities was considered homogeneous with all other installations.

The survey consisted of 17 questions. Questions 1 through 4 were designed to obtain water service data for FY 1982 and 1983 which had not been

Table 3

Published Sources of Information

Type of Information	Source
Historic weather-related data	*Local Climatological Data* (National Oceanic and Atmospheric Administration, 1982a)
	Climatological Data of the States (National Oceanic and Atmospheric Administration, 1982b)
	Summer Precipitation and Potential Evaporation Contour Maps (Hittman Associates, Inc., Vol 11, 1969)
Historic population data	*Distribution of Personnel by State and by Selected Locations* (Department of Defense, 1982).
Historic housing requirements	*Determination of Housing Requirements* (Department of Defense Report 1378)
Map Book	*Major Military Installations* (Department of Defense, 1980)
Installation Directories	*Department of the Army* (U.S. and World Government Installation Directory Service, 1982)
	Department of the Army (U.S. Organization Chart Service, 1983)
	"Guide to Military Installations in the United States" (The Times Magazine, 1982 and 1984)
	Temporary Military Lodging (1981)

Table 4

Characteristics of Visited Installations

Installation	Major Command Jurisdiction	Principal Activity	Location
Fort Campbell	FORSCOM	Readiness	Kentucky
Fort Bragg	FORSCOM	Readiness	North Carolina
Fort Sill	TRADOC	Training	Oklahoma
Fort Bliss	TRADOC	Training	Texas
Fort Belvoir	TRADOC	Training	Virginia
White Sands Missile Range	AMC	Test & Evaluation	New Mexico
Red River Army Depot	AMC	Supply Depot	Texas
Pine Bluff Arsenal	AMC	Arsenal	Arkansas
Harry Diamond Laboratories	AMC	Laboratory	Maryland
Walter Reed Army Hospital	HSC	Hospital	District of Columbia
Fort Huachuca	ACC	Communication	Arizona
Fort McNair	MDW	Capital Support	District of Columbia

available due to nonpublication of the Redbook. Questions 5 through 16 are directly related to the three areas of desired information described above and the first objective of this research. The questionnaire was pre-tested at four installations before releasing it to the others. No revisions were required, and respondents were able to complete the questionnaire in about 2 hours.

Table 5 summarizes the 86 respondents by job title. The average number of years employed of each respondent was 5½ years, with a range from 1 month to 25 years. One respondent did not furnish a job title, and three respondents did not indicate years of service. The cover letter to DEH had requested that the respondent chosen to answer the questionnaire be knowledgeable and experienced in the planning, operation, and maintenance of water supply activities and occupy a principal management position in this area. The listing appears to verify that most respondents were selected to comply with this criterion.

The pre-test was mailed on 26 December 1983, followed by the first phase of the overall general mailing. Eight questionnaires were sent on 28 December 1983 to the remaining posts included in the installation visit itinerary. The cover letters were modified to instruct the DEH at each post to retain the questionnaire for personal review and pickup during on-site discussions. The general initial mailing was released on 11 January 1984 with a requested reply date of 25 January 1984. Reminder letters were sent at about 1-month intervals, and the last response was received on 14 May 1984. The elapsed time for the survey was 141 days and produced 86 responses for a return rate of 92.5 percent (Table 6). The principal investigator conducted all phases of the entire survey operation, including questionnaire design, mailing, interviewing, data collection, coding, tabulation, and analysis; this reduced potential reliability problems associated with the use of coding terms. Each questionnaire received was edited to detect and eliminate as much as possible errors in the completed reply. Mailed returns were checked and missing entries were noted in 14 questionnaires. In most cases, a followup point of contact with telephone number had been indicated, and when it was verified that the point of contact was also the original respondent, the missing data were obtained by telephone. A frequency analysis was used to describe the results. Hypothesis testing to determine systematic relationships between joint frequencies was done by Chi-square analysis.

Table 5

Survey Respondent Job Title and Frequency

Title	Absolute	Frequencies Relative (%)	Cumulative (%)
Chief/Assistant Chief of Utilities	18	20.9	20.9
Environmental Supervisor/Engineer/ Specialist/Coordinator	18	20.9	41.8
Director/Chief/Manager of Engineering and Housing or Facility Engineering	14	16.3	58.1
Chief, Sanitation Branch	8	9.3	67.4
Foreman/Supervisor, Water Treatment Plant or Main Pumping Station	6	7.0	74.4
Engineering Supervisor/Engineer/ Technician	6	7.0	81.4
Chief, Environmental/Natural Resources Branch	4	4.6	86.0
Chief, Maintenance Division	2	2.3	88.3
Master Planning Chief/Planner	2	2.3	90.6
Chief/Engineer, Mechanical Engineering Branch	2	2.3	92.9
Chief of Operations	2	2.3	95.2
Subarea Commander	1	1.2	96.4
Deputy Director of Engineering and Housing	1	1.2	97.6
Administrative Officer	1	1.2	98.8
(Missing Job Title)	1	1.2	100.0
TOTALS	86	100	100.0

Table 6

Survey Mailing Results and Response Summary

Survey Activity	Mailing Dates	Number of Mailings	Number of Responses
Pre-test mailing	26 December 1983	4	4
Initial mailing (cover letter and questionnaire)	28 December 1983 (Phase I)	8	8
	11 January 1984 (Phase II)	81	45
First reminder letter	6 February 1984	36	25
Second reminder letter with questionnaire	12 March 1984	11	4

Summary:

Target number of installations - 93

Number of responses - 86

Response rate - 92.5%

3 WATER SERVICE AND RELATED MANAGEMENT PRACTICES WITHIN THE STUDY AREA

The NDI study predicted rising costs by the year 2000 for water service on Army installations. Expansion capabilities of Army posts may be constrained by inadequate water service, implying the need for accurately estimating current capabilities and for preparing contingency plans in case of water shortages. When properly planned, water conservation programs can attenuate these adverse impacts, but a lack of incentive to investigate the benefits of potential conservation measures may result in indifference by planners at the installation level.

Is the Army actually experiencing a pattern of rising water-related costs? Are water requirement studies being undertaken and contingency plans being developed for potential water shortage situations? Is water conservation being practiced? The answers found in this study tend to verify the conclusions of the NDI assessment.

This chapter characterizes water service and the state of water planning within the study area. Average daily water use for the 90 installations during FY 1981 is described relative to mission orientation (i.e., Major Command and water sources). Analysis by population size and per capita water use indicators would be misleading because of errors in population measurement (see Chapter 4). The analysis concentrates on the status of water planning and conservation practices among Major Commands. Data obtained from the survey are analyzed to provide a perspective on the scope and intensity of the water planning effort in the study area.

The distribution of unit costs for water service operation and water system maintenance and repair are analyzed by mission orientation and sources of water supply. Average unit costs are provided to determine the significance of trends for the period FY 1975 through FY 1981.

Eight Major Commands control the individual installations listed in the FY 1981 Redbook (Table 7), and the Military District of Washington controls three subordinate stations in the Metropolitan area of Washington, D.C. Within each command, the installations are generally distributed throughout the study area, and there are no discrete geographical boundaries among them. The common acronyms of the Major Commands will be used to represent the mission orientation of corresponding installations. (A listing of installations by Major Command was given in Table 1.) Eighty-three installations represented the Major Commands in both the FY 81 Redbook and the survey, which facilitated a joint analysis between the two databases.

Table 7

Major Command Identification and Selected Characteristics

Major Command Designation	Common Acronym	Number of Installations Within the Study Area: FY 81 Redbook	Number of Installations Within the Study Area: Survey Respondent	Mission Orientation
Forces Command	FORSCOM	22	20	Operations and unit readiness.
Training and Doctrine Command	TRADOC	21	18	Manages individual soldier training; commands the Army's service schools; development of doctrine and training publications.
Army Materiel Command	AMC	35	33	Manages the Army's total logistics system and controls various research and development and materiel readiness installations.
Intelligence and Security Command	INSCOM	2	2	Intelligence collection and production, counterintelligence, and security.
U.S. Army Communications Command	USACC	2	2	Plans, engineers, installs, and operates the Army's portion of the Defense Communications System and for other Army communications and air traffic control facilities.
Military Traffic Management Command	MTMC	4	4	Manages all military traffic, land transportation, and common-user ocean terminals.
Health Services Command	HSC	3	3	Manages and delivers health care and supportive services and supervises medical training for the Army.
United States Military Academy	USMA	1	1	Provides the Army with well-educated and highly trained professional Army officers.
Military District of Washington	MDW	NA	3	Responsible for designated Army functions in the metropolitan area of Washington, D.C
	TOTALS:	90	86	

Water Service Patterns Within The Study Area

Installations may have either single or multiple sources of water supply. Water service may depend on acquired surface or ground water sources of transmission; filtration and distribution are done by the DEH workforce. Post water may be purchased from local civilian communities and transmitted to the installation for delivery through its distribution system. Army Regulation 37-100-81[6] defines purchased water as the total quantity of water purchased under utility contracts. Purchased water is either surface or ground water, but is discussed here as a separate entity to point out that installations are not necessarily self-supporting. The total average daily water requirement for all 90 installations in FY 1981 was 163.1 million gal per day (mgd). The mean value per installation was 1.8 mgd, with a low value of 12,000 gpd to a high of 9.8 million gpd. The distribution of average daily water use was assessed and is shown by source with further disaggregation by Major Command in Table 8.

Single Versus Multiple Sources of Water Supply

Forty-two installations (46.6 percent) obtain their daily water needs from a single source and together account for 18 percent of the total water used on an average day within the study area. The remaining 48 installations are serviced by multiple sources, which account for 133.73 mgd, or 82 percent. Within the categories of single sources, purchased water from local civilian communities ranks the highest in terms of total water needs (15.1 mgd) among single-source installations; however, on an installation basis, stations depending on ground water consume greater average daily quantities of water (1.47 mgd) than either those that purchase water (0.36 mgd) or those that use a surface water source (.63 mgd).

Among multiple-source posts, the dual combination of purchased and surface water (52.25 mgd) or purchased and ground water (22.60 mgd) satisfies the needs of 29 installations (32 percent). Nearly one third of all water (51.9 mgd) required on an average day by all installations in the study area is provided by systems which combine all three water sources.

The larger users (above the grand mean of 1.8 mgd) are served by multiple sources. Average use by an installation ranges from 0.25 mgd to 5.73 mgd, with a mean for all multiple-source installations of 2.79 mgd. On the other hand, single-source installations reflect a range of 0.10 mgd to 2.05 mgd, with a mean for all single-source installations of 0.70 mgd.

[6] Operation and Maintenance, Army, 1981, Army Regulation 37-100-81 (Department of the Army [DA], 1981b).

Table 8

Installation Mean Average Daily Water Requirements by Major Command and Source of Water Supply
(Millions of Gallons Per Day)

Major Command (Mission Orientation)	Sources of Water Supply: Single Source			Multiple Sources				Totals	Percentage of Total Average Daily Water in Study Area
	Purchased	Ground	Surface	Purchased + Ground	Purchased + Surface	Ground + Surface	Purchased + Ground + Surface		
FORSCOM	0.47(4)*	0	0	5.73(2)	3.06(12)	0	3.66(4)	64.70(22)	39.7
TRADOC	1.22(5)	2.05(1)	0.10(1)	1.98(4)	2.97(4)	2.26(1)	4.26(5)	51.61(21)	31.6
AMC	0.45(9)	1.33(5)	0.41(9)	0.25(1)	0.29(3)	1.18(4)	3.88(4)	35.75(35)	21.9
USACC	0	0	0	0	2.68(1)	0	0.44(1)	3.12(2)	1.9
HSC	1.08(2)	1.59(1)	0	0	0	0	0	3.75(3)	2.3
INSCOM	0.16(1)	0	0.23(1)	0	0	0	0	0.39(2)	.3
MTMC	0.25(3)	0	0	0	0.10(1)	0	0	0.85(4)	.5
USMA	0	0	0	2.97(1)	0	0	0	2.97(1)	1.8
Total Average Daily Requirements	15.10(24)	10.29(7)	4.02(11)	22.60(8)	52.25(21)	6.98(5)	51.90(14)	163.14(90)	100
Percentage of Total Average Daily Water in Study Area	9.3	6.3	2.5	13.8	32.0	4.3	31.8	100	

*Average values are shown for the number of installations given in parentheses.

Water Use by Mission Orientation

Forces Command (FORSCOM), Training and Doctrine Command (TRADOC), and Army Materiel Command (AMC) collectively account for 93.2 percent of the water needs within the study area. FORSCOM uses the greatest proportion (39.6 percent) of the total daily water requirement, followed by TRADOC (31.6 percent), and then AMC (21.9 percent). A comparison of the mean values for all installations within each of these three Major Commands reveals the same rank ordering. A typical installation in FORSCOM uses 2.94 mgd, which is about 20 percent more than the average TRADOC post (2.45 mgd) and almost twice as much (188 percent) as an average AMC installation (1.02 mgd). It can also be observed that both FORSCOM stations (82 percent) and TRADOC posts (67 percent) are predominantly multiple-source. The reverse is true for AMC installations, where 66 percent of all the installations with a mission orientation of logistics supply or materiel development and testing receive their water from single sources. When the remaining five commands were grouped into a single category termed "all others," it was determined that the average daily water requirement was 0.92 mgd per installation--and considerably below the average for the entire study area (1.8 mgd).

Water Use by Total Building Area

An additional qualifier of average daily water use was sought to explain partially why FORSCOM and TRADOC installations generally use water quantities greater than the mean. It may be that the posts with these mission alignments provide water service to larger-than-average populations. Unfortunately, population data are suspected of being measured incorrectly (see Chapter 4). An alternative measure is the total gross floor area of all buildings located on each installation. Moreover, building floor area is a kind of surrogate for population, and the types of buildings can also suggest an installation's mission orientation. Within the study area, the mean value for total building area is 6.7 million sq ft, with a minimum value of 131,000 sq ft and a high value of 23.1 million sq ft. It is reasonable to suspect that installations with greater-than-average total building areas would also likely be greater-than-average water users. Having observed that FORSCOM and TRADOC installations are generally above-average users, then it is also likely that they also have greater-than-average building areas.

Statistical Analysis of Water Use Relationships

These observed or suspected relationships were used to formulate corresponding hypotheses and were empirically tested, using joint frequency analysis between pairs of variables representing average daily water use, source of water, mission orientation, and total building floor area. Average daily water use was divided about the population mean to distinguish installations which were "above-average" and "below-average" water users. Sources of water were grouped into the two principal categories of "single" or "multiple" sources. Mission orientation was represented by each installation's parent Major Command. Total building square footage was also separated at the population mean for this variable. In each hypothesis examined, the statistical analysis failed to reject the null hypothesis that the observed frequencies were not different from the expected distribution (Table 9). Moreover, examination of the individual cells in each test verified the observations provided by Table 8. Total building area was strongly related to average daily water use, as indicated by the high level of statistical significance of the Chi-square, and there is a significant positive correlation between above-average water use and above-average building floor area ($r = 0.674$). Also, the total building area depends partly on the installation's mission orientation. Again, FORSCOM and TRADOC installations were found to have above-average total building areas. Logistical installations (AMC) and, generally, the remaining Major Commands use less-than-average daily water quantities and are also below average in total building gross floor area.

Conclusions Related to Water Use Patterns Within the Study Area

Installations that use more than about 1.8 mgd are likely to have the mission orientations of FORSCOM and TRADOC (operational readiness and soldier training), multiple sources of water supply, and above-average total building floor area. Installations that use less than 1.8 mgd are likely to have missions related to logistical support and materiel development (AMC), single-source water supplies, and a below-average total building floor area.

Water Planning Insights From Installation Visits

Except for two installations in the Southwest, water supplies were considered more than adequate for present and future peacetime requirements. This consensus was usually based on the judgment that water service was being operated below water system capacities. At the same time, however, studies had not been done on these installations to determine the major users of water and quantities of water used. The absence of water studies was generally attributed to the lack of water meters. Water utility personnel conceded that water losses and water waste are occurring but have not been quantified. The potential dollar benefits of water conservation measures are not viewed from the perspective of reducing loss or waste of water. Water service operation and system maintenance costs are considered small, compared to energy costs which are receiving major planning emphasis and a well-defined conservation effort. In fact, water conservation is encouraged primarily to reduce energy costs.

Table 9

Joint Frequency Analysis of Average Daily Water Use Patterns

Dependent Variable	Independent Variable	Chi-Square	Degrees of Freedom	Level of Significance	Pearson's R	Level of Significance
Average Daily Water Use	Major Command	20.347	7	0.0049	-0.318	0.0011
Average Daily Water Use	Source of Water	28.928	1	0.0001	0.567	0.0001
Average Daily Water Use	Total Building Area	40.833	1	0.0001	0.674	0.0001
Source of Water	Major Command	23.404	7	0.0014	-0.369	0.0002
Source of Water	Total Building Area	14.405	1	0.0001	0.400	0.0001
Building Area	Major Command	20.490	7	0.0046	-0.353	0.0003

Army Regulation 420-16[7] provides guidelines for computing the expansion capability of an installation to support the water requirements of increased soldier numbers and related equipment. There is no corresponding requirement to prepare a separate forecast of water use in a peacetime setting. However, in calculating mobilization water requirements, it is necessary to estimate nonmobilization water requirements that will continue to use installation supplies during a buildup operation.

The procedures employed estimate average daily water use based on recent historical per capita use and are discussed in detail in Chapter 4. The procedures assume that the derived per capita figure is appropriate for computing peacetime requirements, regardless of when mobilization would occur. At least three observations can be made that cast doubt on the reliability of the estimation involved in this procedure. If one accepts the peacetime water use approximation, will it continue to be valid in 5 years, 10 years, or longer? Is peacetime water use expected to increase or decrease in these future time horizons? The procedure assumes that nonmobilization water use will remain as it was when the study was conducted. Second, the per capita estimation technique assumes homogeneous water use throughout the installation and does not offer a means to assess separate impacts on domestic, commercial, or industrial water, which may differ considerably in a mobilization setting. Finally, water conservation measures are expected to enhance water availability during expansion, but the full range and types of potential conservation actions are not identified, assessed, or rank-ordered.

It is clear from these installation visits that water service planning needs improvement in predicting peacetime water use, identifying sectoral use, and evaluating potentially beneficial conservation measures.

Future Expectations of Water Source Requirements

Installation water utility managers were asked to indicate whether purchase of water will increase, decrease, or remain about the same by FY 1990. The same question was asked regarding surface and ground water sources. Seven Redbook installations did not respond to the survey, and three posts from the Military District of Washington which did reply are not identified individually in the Redbook database.

The percentages for each source have been adjusted to exclude posts where the source is not applicable or is under consideration as a potential supplemental source (Table 10). Purchase of water is expected to increase on 12 installations. Surface and ground water requirements are also anticipated to increase on nine and 19 installations, respectively. Within each source category, about half of the installations are expecting current-source water requirements to remain about the same. Many respondents (29 separate

[7] Facilities Engineering Reports, Army Regulation 420-16 (DA, 1983).

installations) did not know if source requirements would increase, decrease, or remain the same by FY 1990.

Installation water service planners and managers were asked if a study had been done in the past 5 years that included a forecast of future installation water needs. Of 86 respondents, 63 indicated "no" (73 percent), while 22 (26 percent) indicated "yes"; one respondent noted that a study was now being done. Of the 22 completed studies, 82 percent are based on a per capita or adjusted per capita forecasting method. Although only about one fourth of all responding installations have apparently evaluated water needs for the future using a method that goes further than judgmental planning, at least half the installations reported their future water needs were uncertain or would increase. Therefore, there are voids in water service planning and forecasting that require more emphasis and improved forecasting studies to substantiate current expectations.

Water Shortage Contingency Plans

A short-term water shortage may occur because of drought, contaminated water quality, major breaks in transmission or distribution lines, pumping station or treatment plant interruptions, emergency mobilization requirements, or combinations of any of these. Water shortages caused by drought, equipment failure, and contaminated supplies have occurred on Army installations and warrant well-prepared and coordinated plans.

Fifty-one (60 percent) installations responding to the survey indicated no documented plans were on-hand. One installation did not answer the question. To determine if there was a significant relationship between water emergency contingency plans and mission orientation, a two-way analysis of joint frequencies was conducted, with "contingency plans" as the dependent variable and Major Command as the independent variable (Table 11). Major Commands with four or fewer installations were grouped into an "all others" category. The specific objective was to see if FORSCOM and TRADOC installations have a greater-than-expected occurrence of water contingency plans, as suggested by their mission orientation, above-average water use, and larger-than-average service area (building gross floor area). The test results indicate a strong relationship between contingency plans and mission orientation, with a Chi-square level of significance at 0.0001. The analysis also shows that FORSCOM and TRADOC installations together account for 25 (68 percent) of the total 34 installations reporting on-hand contingency plans. In contrast, DARCOM installations exceed expectations for "no plans," having 29 (57 percent) of all the posts in this response group. It is apparent that stations supporting major troop units in a readiness posture are more likely to be sensitive to potential water supply emergencies than are posts with materiel acquisition or storage functions, and thus prepare contingency plans accordingly.

Table 10

Water Requirements From Existing Sources: FY 1990 Expectations of Installation Water Planners and Managers
(Number of Installations)

Expectation	Source of Supply* Purchased Water No.	%	Surface Water No.	%	Ground Water No.	%
Increase	12	(21.0)**	9	(19.6)	19	(29.2)
Decrease	1	(1.8)	0	(0)	3	(4.6)
Remain about the same	26	(45.6)	23	(50.0)	29	(44.6)
Don't know	18	(31.6)	14	(30.4)	14	(21.6)
Source not applicable	29		40		21	
Total Respondents	86	(100)	86	(100)	86	(100)

*An installation may be included in more than one category if it depends on multiple sources.
**Percentages in parentheses are relative frequencies adjusted to exclude "source not applicable" responses.

Table 11

Water Shortage Contingency Plans and Mission Orientation

Contingency Plan Status	Mission Orientation FORSCOM N*	%	TRADOC N	%	AMC N	%	All Others N	%	Total N	%
None	6	11.8	8	15.7	29	56.9	8	15.6	51	60.0
Plan Prepared	14	41.2	9	26.5	4	11.8	7	20.5	34	40.0
TOTAL	20	23.5	17	20.0	33	38.8	15	17.7	85	100.0

*Number of responses
Chi-Square = 29.472 with 3 degrees of freedom (d.f.)
Probability Significance <.0001

A greater number of single-water-source installations than expected do not have contingency plans, while posts with multiple sources have more plans than expected. Using the status of contingency plans as the dependent variable, its distribution throughout the population was examined in terms of its correspondence with the frequency of single or multiple sources of water. The relationship was significant at the 0.02 level, with a Chi-square value of 5.362. The correlation between the two variables was positive, with r = .251, significant at a level of 0.01 probability. This finding raises concern regarding installations without plans and that depend on a single source of water supply. Reserve supplies may be readily available, but procedures to get the supplies released during an emergency are not documented. Water utility managers would be well-advised to prepare a written plan for minimizing costs when dealing with a crisis situation.

Table 12 shows the types of emergencies planned for by the 34 installations that have written plans. Grouping the individually coded categories into single themes shows that the water shortage most frequently planned for is drought (18 plans), followed by contingencies to engage emergency mobilization water needs (14 plans). Eight installations have planned for contaminated water quality and an equal number have documented plans to relieve water shortages due to a mechanical failure in the water system or a power outage. However, most installations responding to the survey have no plans on hand.

Recent Water Conservation Programs

Information pertaining to water conservation activities was sought to ascertain the extent and kinds of recent conservation measures implemented at Army installations. In response to the question, "Has your installation implemented a water conservation program within the past five years?", 55 (64 percent) installations reported that they had not done so, 30 (35 percent) indicated "yes," and one installation did not respond to this question. The 30 positively responding installations identified a combined total of 80 water conservation measures which, for the most part, were briefly described with reasons for selection and results of implementation.

Water Conservation Programs Within Major Commands

Statistical tests showed no systematic relationship between the distribution of implemented conservation program and mission orientation. It was expected that implementation of conservation programs would be more likely at FORSCOM and TRADOC installations than at AMC and "All Other" Major Commands. Applying a criterion of 0.05 probability level for the significance of the Chi-square statistic, it was found that the relationship between practiced conservation programs and mission orientation was not significant (Table 13) for the surveyed population. Examination of the patterns between Major

Table 12

Water Shortage Contingency Plans

Type of Contingency	Installations No.	%
No Documented Plan on Hand	51	(60.0)
Drought	8	(9.4)
Emergency Mobilization	5	(5.9)
Contaminated Water Quality	3	(3.5)
Mechanical Failure	7	(8.2)
Drought and Mobilization	5	(5.9)
Drought and Contaminated Quality	2	(2.4)
Mechanical Failure and Mobilization	1	(1.2)
Drought, Mobilization, and Contaminated Quality	3	(3.5)
(Mission Response)	1	--
TOTAL	86	100

Table 13

Water Conservation Programs and Mission Orientation

Water Conservation Program Status	Mission Orientation: FORSCOM N*	%	TRADOC N	%	AMC N	%	All Others N	%	Total N	%
No program	13	22.6	8	14.6	25	45.4	9	16.4	55	64.7
Program implemented in the past 5 years	7	23.3	9	30.0	8	26.7	6	20.0	30	35.3
TOTALS	20	23.5	17	20.0	33	38.8	15	17.7	85	100

*Number of Respones
Chi-square = 3.784 with 3 d.f.
Probability Significance = 0.466

Commands revealed that FORSCOM installations account for 13 (44.8 percent) of the total implemented programs, which is identical to the expected distribution quantity. However, TRADOC installations account for 11 (37.9 percent) of all implemented programs in the study area, which does exceed statistical expectations. Logistically oriented posts and the comparatively smaller Major Commands exhibit fewer programs than expected based on the population distribution, but collectively, the relationship is weak. Water conservation programs are generally distributed without significant difference throughout all Major Commands, and the presence of an operationalized water conservation program is not significantly related to mission orientation.

Water Use and Water Conservation Programs

The occurrence of executed water conservation programs is systematically related to the average daily water use pattern throughout the installations surveyed. This confirms the hypothesis that water conservation programs are likely to occur on installations with above-average water use. With the "status of water conservation" as the independent variable, the joint frequency analysis resulted in a Chi-square value of 7.745, significant at the 0.0054 level for one degree of freedom (Table 14). More than three fourths of the installations with no water conservation programs are below-average water users, and more than one half of the posts with water conservation programs produced within the past 5 years are above-average users. The correlation coefficient ($r = .307$) was also highly significant, so the hypothesis cannot be rejected. Water use data were not available for the three stations in the Military District of Washington.

Types of Conservation Measures Being Implemented

Restrictions and bans are most frequently implemented, and collectively account for 55 percent of the aggregate total (Table 15). Irrigation restrictions of lawn areas and golf courses include alternate-day, time-of-day, and percent reduction controls. Bans or limitations on washing privately owned cars and military tactical vehicles are also imposed. The primary reason for selecting these measures is to reduce nonessential water use during dry summer periods or drought; enforcement is by the post military police. These measures are short-term mitigation actions during an emergency water shortage. Results of implementation expressed by the study participants are qualitative, not quantitative. For example, responses include, "Quick way of coping with an emergency," "Met water reduction goal and no impact on mission," "Satisfactory reduction," and "Used less water."

Technological measures include flow-restrictive plumbing fixtures or devices for faucets, showerheads, and toilets. Among the reasons cited for choosing these measures were "To conserve water," "Energy conservation suggestion," "Reduced utility energy consumption," and "Cost-effective."

Table 14

Water Conservation Program Status and Average Daily Water Use

Status of Water Conservation Program	Average Daily Water Use				Total	
	Below Average		Above Average			
	N*	%	N	%	N	%
No Program	40	76.9	12	23.1	52	63.4
Program implemented within past 5 years	14	46.7	16	53.3	30	36.6
TOTALS	54	65.9	28	34.1	82	100.0

*Number of Responses
Chi-square = 7.745 with 1 d.f.
Probability Significance = 0.0054
r = .307
Significance = .0025

Table 15

Summary of Recently Implemented Conservation Measures

Type of Measure	Description	Reported as Having Applied During Past 5 Years No.	%
Restrictions/Bans	Family/bachelor soldier lawn areas	15	(18.7)
	Golf course irrigation	12	(15.0)
	Car washing	9	(11.2)
	Tactical vehicle washing	8	(10.0)
Technology	Shower flow-control devices	11	(13.8)
	Reuse/recycle systems	8	(10.0)
	Faucet flow restrictors	3	(3.8)
	Water-efficient tank commodes	2	(2.5)
Institutional	Leak detection studies	3	(3.8)
	Water conservation regulations	2	(2.5)
	Inspection of hot water heaters and boilers	2	(2.5)
	Centralizing tactical vehicle wash areas	1	(1.2)
	Conversion to desert landscape	1	(1.2)
Educational	Requesting voluntary cutbacks through various media	3	(3.8)
TOTALS		80	(100.0)

Installation of shower flow-restrictors resulted in customer complaints at four posts; in one case, they are being removed. Six installations have not measured water reduction resulting from these devices; only one respondent stated the average daily quantity reduction per family attributable to these devices. Other conservation measures taken were reusing treated wastewater to irrigate the golf course and to wash military vehicles, and recycling water in cooling and heating processes to reduce makeup quantities. These actions produced in large water reductions and related energy cost savings.

Two installations had implemented post-wide water conservation programs through a regulation requiring compliance by all installation water users. One post indicated this had reduced water consumption by about 2 million gpd during dry summer months. Additional institutional measures, such as leak detection studies, centralization of tactical vehicle wash areas, and inspection of hot water heaters and boilers by the DEH workforce have been implemented. One post in the Southwest has begun selected conversion from grassed landscape to desert landscape to reduce irrigation water requirements.

Educational programs have been attempted at three installations where the emphasis has been to request voluntary cooperation by residents during peak water demand periods or to reduce water waste. Examples include showering only once a day and washing dishes or laundry with a full load.

Conclusions Pertinent to Water Conservation Planning

Water conservation programs are systematically related to patterns of average daily water use. Installations with above-average daily water requirements are likely to have implemented a water program within the past 5 years, while those with below-average daily needs tend to not have a conservation program. The presence of an executed conservation program is not significantly related to mission orientation. Installations must individually determine the potential benefits of specific water conservation measures, with no real incentives to pursue such a study.

The information obtained from the survey suggests that the types of conservation measures being implemented are limited, relative to the number identified in the literature. Dziegielewski[8] cites numerous references where listings can be obtained. Visits to 12 installations indicated either a lack of information regarding a broad range of potential water conservation measures or, when known, how to choose which would be the most effective and

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[8] B. Dziegielewski, D. D. Baumann, and J. J. Boland, The Evaluation of Drought Management Measures for Municipal and Industrial Water Supply, Report No. 83-C-3 (Institute for Water Resources, U.S. Army Corps of Engineers, 1981).

efficient. Two recent reports[9] review domestic plumbing fixtures for water reduction and irrigation control practices which can be considered by installation water managers.

There also does not appear to be a planning procedure for selecting water conservation measures. Short-term emergency measures have generally reduced water use during shortages, as shown in the responses of the survey participants; however, it is not known whether implementation costs could have been lessened by selecting alternatives that might also have attained the desired reduction goal. In an emergency, best judgment must prevail by evaluating applicable, on-hand information. The Corps of Engineers Institute for Water Resources recently published guidelines for determining optimal strategies for water shortage mitigation in municipal and industrial water supplies[10] that may be adaptable to the water planning needs of military installations. However, both short-term measures to cope with emergency shortages and long-term conservation actions that would beneficially reduce water loss and waste require a procedural framework to help planners identify and evaluate them.

Water Service Operation and System Maintenance Costs

The NDI study warned that water service could be expected to incur higher expenditures, both for production on-post and for reimbursing local communities that provide water to Army installations. Data in the Redbooks for Fiscal Years 1975 through 1981 were analyzed to determine if costs have been rising in both operations and maintenance. Fiscal Year 1981 cost data were further analyzed to determine the presence and extent of relationships with patterns of water use, mission orientation, and water supply sources.

The Redbook data segregate water costs into two categories: operational (water service costs) and maintenance and repair (water system costs). Operational costs include purchased water and the operation of water treatment plants, including pumping at both treatment and source plants. Maintenance and repair costs are for sources of water supply, water distribution systems, treatment and filtration plants, equipment for pumping, and water storage. The Redbook does not give capital expenditures for water system expansion or major component replacement.

To measure recent patterns, 81 installations having continuous data reported throughout the 7 years of records were identified. Unit costs for total operations were computed by dividing the total annual cost for water

[9] R. J. Scholze, L. J. Benson, M. A. Kamiya, M. J. Staub, and J. T. Bandy, Water Conservation Methods for U. S. Army Installations: Volume I, Residental Usage Management, Technical Report N-146/A128550 (USA-CERL, 1982); R. J. Scholze, L. J. Benson, M. A. Kamiya, M. J. Staub, and J. T. Bandy, Water Conservation Methods for U.S. Army Installations: Volume II, Irrigation Management, Technical Report N-146/A128516 (USA-CERL, 1983).

[10] Dziegielewski, Baumann, and Boland, 1983.

service by the total annual quantity of water given in 1000-gal units to arrive at a unit cost in dollars per 1000 gal. Unit maintenance costs were derived similarly by dividing by the total annual quantity of water. This procedure also enables the unit costs for each category to be summed to provide a perspective of total costs for these two categories. Annual unit costs represent the average of the unit costs of the 81 installations (Table 16). Average costs are shown in both nominal (current) and 1983 dollars. The constant dollar figures were obtained by inflating current dollar data according to changes in the Gross National Product implicit price deflator. This procedure approximates the effect of cost changes on the total economy and has been used similarly by Boland[11] to describe water utility cost/time trends.

Nominal costs for both operations and maintenance and repair increased at the average rates of 15.9 percent and 18.9 percent per year, respectively. Inflation during this period would partially explain an increase; however, these average percentages exceed average inflationary rates for the same period. The constant dollar pattern, with the effects of inflation removed, shows that operational costs are still increasing at an average annual rate of 4.60 percent. Maintenance and repair costs are growing at an average annual rate of 6.48 percent (1983 dollars). Total average costs for the summed categories are also rising at a 5.45 percent average annual rate. It is likely that installation maintenance and repair costs for systems approaching the end of their expected economic lives will grow in the near future and continue to influence time trends in an increasing direction.

Unit average costs are further examined in the following sections to determine patterns across all installations in the study area. Average costs for water service operations during Fiscal Year 1981 are analyzed to determine significant relationships with selected variables.

Operating Costs and Water Use, Mission Orientation, and Water Supply

Unit costs for water service operation in FY 1981 ranged from $.03 per 1000 gal ($/k-gal) to $2.87/k-gal. The median value for all 90 installations was $.53/k-gal, with a standard deviation of $.51 ($/k-gal).

Statistical analysis of the relationship between average unit water costs and water use, mission orientation, and water supply revealed the following:

1. Army installations with average daily water use above the mean are likely to have average unit operating costs below the mean for the 90

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[11] J. J. Boland, Water/Wastewater Pricing and Financial Practices in the United States, Technical Report 1, MMI 19-83, prepared for Near East Bureau of the Agency for International Development, Washington: Metometrics Inc. (1983b).

Table 16

Average Operation and Water System Maintenance and Repair Costs for 81 Installations in Current and 1983 Dollars ($/Thousand Gallons Produced)

Fiscal Year	Water Service Operating Expense	Water System Maintenance and Repair Expense	Total Expenditure
Current Dollars:			
1975	0.233	0.194	0.427
1976	0.289	0.244	0.533
1977	0.293	0.285	0.578
1978	0.313	0.327	0.640
1979	0.384	0.338	0.722
1980	0.416	0.301	0.717
1981	0.492	0.451	0.943
1983 Dollars*:			
1975	0.413	0.344	0.757
1976	0.484	0.409	0.893
1977	0.461	0.449	0.910
1978	0.457	0.478	0.935
1979	0.512	0.451	0.963
1980	0.506	0.366	0.872
1981	0.546	0.500	1.046

*Current dollar values inflated by Gross National Product fixed weight implicit price deflator (Council of Economic Advisors, 1984, p 226).

(Source: Based on raw data from the Redbook, Office of the Chief of Engineers, 1982, 1981a, 1980, 1979, 1978, 1977, and 1976 for 81 Army fixed installations located in the contiguous United States.)

installations (Table 17a). Stations with below-average daily water use are likely to have above-average unit costs.

2. Installations assigned to FORSCOM and TRADOC have lower than average unit costs, and AMC and "All Other" installations have a greater than expected number of posts with higher than average unit costs.

The relationship between average unit operating costs, measured by Chi-square, was significant below the 0.05 criterion level (Table 17b). Installations providing water service from a single source of supply are likely to have higher than average unit costs for water service operation. Posts with multiple sources of water have expanded options and can mix source withdrawals to coincide with a least cost solution and have lower than average operating costs. A two-way frequency analysis confirmed a statistically significant relationship between average unit operating costs and water source complexity (Table 18). The correlation coefficient ($r = -0.282$) is consistent with this relationship.

Summary of Water Planning and Related Patterns of Water Use

Average daily water use during Fiscal Year 1981 was assessed to determine the characteristics of above-average users versus below-average users. By dividing the 90 installations at the mean population value of 1.8 million gpd, it was statistically determined that installations requiring daily quantities of water above this mean value were generally oriented toward missions of operational and deployment readiness or intensive soldier training, had multiple sources of water supply, and contained above-average total gross floor area for all buildings. Installations below the population mean for average daily water use were usually aligned with logistical support or materiel development missions, had one source of water supply, and had less total building floor area.

Installations representing these various missions' functions were visited to gain insight into how these characteristics impact on water planning and preparedness. In most cases, installation water utility managers appeared confident that future water needs could be adequately sustained with existing water sources and water system capabilities. There appeared to be few incentives for evaluating the potential benefits of conservation measures, unless a proposed measure suggested a concurrent dollar savings in energy consumption reduction.

However, the results of a mail survey to which 86 installations responded indicated more than one third did not know what quantities of water would be needed to support Fiscal Year 1990 requirements. Even among posts that adjudged a general direction in future water needs (increase, decrease, or similar to FY 1983 levels), only about one fourth of the reporting stations have apparently evaluated water needs for the future using a planning method that goes beyond judgmental planning. The 22 water use forecasts that have been

Table 17

Selected Relationships With Average Unit Operating Costs

a. Average Unit Operating Costs and Average Daily Water Use

Average Operating Costs	Average Daily Water Use				Totals	
	Below Average		Above Average			
	N*	%	N	%	N	%
Below the mean	30	51.7	28	43.8	58	64.4
Above the mean	30	93.8	2	6.3	32	35.6
TOTALS	60	66.7	30	33.3	90	100.0

*Number of Responses
Chi-square = 16.390 with 1 d.f.
Significance = 0.0001
R = -0.427
Signficance = 0.0001

b. Average Unit Operating Costs and Mission Orientation

Average Operating Costs	Mission Orientation								Totals	
	FORSCOM		TRADOC		AMC		All Others			
	N*	%	N	%	N	%	N	%	N	%
Below the mean	17	29.3	16	27.6	21	36.2	4	6.9	58	64.4
Above the mean	5	15.6	5	15.6	14	43.8	8	25.0	32	35.6
TOTALS	22	24.4	21	23.3	35	38.9	12	13.3	90	100.0

*Number of responses
Chi-square = 8.215 with 3 d.f.
Significance = 0.0418

Table 18

Average Unit Operating Costs and Sources of Water Supply

Operating Costs	Sources of Water: Single N*	%	Multiple N	%	Totals N	%
Below the mean	21	36.2	37	63.8	58	64.4
Above the mean	21	65.6	11	34.4	32	35.6
TOTAL	42	46.7	48	53.5	90	100.0

*Number of responses
Chi-square = 7.171 with 1 d.f.
Significance = 0.0074
r = -0.282
Significance = 0.0035

done, however, are based on a per capita or adjusted per capita approach, which does not facilitate the evaluation of water conservation measures.

Indicators of water planning were assessed, and included the status of water shortage contingency plans and water conservation programs. Appendix B summarizes the responses by Major Command. Documented contingency plans are more likely to be found on FORSCOM and TRADOC installations; at AMC stations, where single sources of water supply prevail, there were no particular plans. Most installations (59 percent) indicated they had no plans, which reflects a need to increase emphasis in this area.

There is no water conservation policy disseminated throughout Army installations; as a result, 55 (64 percent) of the surveyed installations indicate they have not implemented a water conservation program within the past 5 years. Moreover, the types of conservation measures being used are limited primarily to irrigation restrictions and reduced-flow plumbing fixtures; in most instances, the benefits or costs of these measures have not been quantified. It would appear that a mandated water conservation policy would provide a stimulus to broaden this water planning effort; however, procedural guidelines are needed to help installation planners evaluate potentially adaptable and socially acceptable conservation actions.

An additional incentive is the recognition that total average costs for water service operation and water system maintenance and repair have been increasingly significantly in constant dollars between 1975 and 1981. These costs are likely to continue to rise, particularly on posts where aging system components will need replacement. Capacity requirements will have to be reevaluated in light of demand reduction opportunities offered by water conservation programs. Within the study area, the average operating costs at FORSCOM and TRADOC installations are typically lower than the mean, while those at AMC and the remaining Major Commands are generally higher than average, probably due to their characteristic single source of water supply.

The information gained from this study shows that water service planning within the study area is inadequate in three areas: forecasting, water shortage contingency planning, and procedural assessment of potential water conservation measures. Recent patterns indicate that average water utility operation, maintenance, and repair costs are increasing annually in real dollars, and will require increasingly larger budget allocations. Improved planning procedures would provide one means of curbing these rising costs.

Computing per capita water use would require using the effective population data entered for each installation in the Redbook; however, there is reason to suspect that the values published are misleading. Installation visits showed that water utility managers and planners rarely refer to water use in per capita measures. They frequently commented that per capita measures, if used, would be subject to large changes, depending on how the census was conducted and whether Reserve or Army National Guard units were present for annual field training. Surges in population caused by these training cycles, as well as by summer seasonal water requirements, would affect per capita water use values. Furthermore, the effective population is not consistently computed by the same staff agency on every installation and was not being calculated by DEH. These observations raised questions about measurement procedures, which are identified and examined in this chapter.

Current Procedures for Estimating Average Daily Water Requirements

Computation of effective population is based on the military-dependent and civilian populations of an installation. The effective population is calculated on a monthly basis by averaging the sum of daily counts of resident military and civilian personnel and their family members and one third of all nonresidents. The annual values given in the Redbook represent the average of the sum of the previous 12-month averages.

Effective population is a key determinant in the current procedures for estimating average installation water requirements. The effective population is multiplied by a multi-purpose capacity factor to yield a design population which is then used to determine the required capacity of the supply works. The required daily demand is the product of the design population and a per capita water allowance of 150 gpd, plus any special industrial requirements and irrigation demands (Figure 2).

Effective population introduces errors into computation of installation water use in two ways. First, this procedure assumes that nonresidents account for one third of the water of residents and that the per capita water use of a bachelor soldier living on post is identical to that of a resident family member. Metering studies at Fort Carson, CO, revealed that civilian nonresident use is more nearly one ninth than one third of the allotted 150 gal per capita per day (gpcd).[12] Matherly[13] metered the water use of soldiers living in troop housing at Fort Carson and found a per capita per day range of 29 to 77 gal during April and June 1977. The proportional weighting scheme

[12] J. T. Bandy and R. J. Scholze, USA-CERL TR N-157, 1982.

[13] J. E. Matherly, M. J. Staub, L. J. Benson, and R. J. Fileccia, Water Usage Profile: Fort Carson, Colorado, Technical Report N-34/ADA053227 (USA-CERL, 1978).

EFFECTIVE POPULATION:

RESIDENT MILITARY AND CIVILIAN PERSONNEL

FAMILY MEMBERS OF THE ABOVE

NON-RESIDENTS
(SOLDIERS, FAMILY MEMBERS, CIVILIANS
WHO COMMUTE TO THE INSTALLATION)

$$\text{EFFECTIVE POPULATION} = \frac{\text{NONRESIDENT POPULATION}}{3} + \text{RESIDENT POPULATION}$$

DESIGN POPULATION:

(EFFECTIVE POPULATION) X (CAPACITY FACTOR)

REQUIRED DOMESTIC DEMAND:

(DESIGN POPULATION) X (PER CAPITA DOMESTIC WATER ALLOWANCE)

REQUIRED DAILY DEMAND:

(REQUIRED DOMESTIC DEMAND) + (SPECIAL-PURPOSE WATER USES)

(INCLUDES INDUSTRIAL, AIRCRAFT-WASH, IRRIGATION, AIR CONDITIONING, OR OTHER DEMANDS)

Figure 2. Current procedures for estimating required daily water service. [(From Water Supply Sources and General Considerations, Technical Manual 5-813-1 (interim use draft) (DA, 1979a.)]

for effective population on this installation during this time would more likely be about 9:3:1 for residents, bachelor soldiers, and civilian nonresidents, respectively.

The second way errors are introduced is in the current procedure for estimating an annual representative value for average effective population, as is shown for each installation in the Redbook. Averaging monthly average effective population values (assuming that they are representative values) to arrive at an annual value for estimating per capita water service leads to error. This problem can be seen by referring to the entries of Table 19, which shows actual monthly data obtained from a study done at Fort Chaffee, AR.[14]

[14]Robert G. Muir and Associates, Emergency Expansion Capability Plan, Steps 1-4, Fort Chaffee, prepared under the direction of the Department of the Army, Fort Worth District, Corps of Engineers, Colorado Springs, CO (1979).

Table 19

Water Data for Fort Chaffee, FY 1978
(From raw data excerpted from Robert G. Muir and Associates, Emergency Expansion Capability Plan, Steps 1-4, Fort Chaffee, prepared under the direction of the Department of the Army, Fort Worth District, Corps of Engineers, Colorado Springs, CO [1979], pp 1-8.)

Month	Total Delivered Water (k-gal)	Average Daily Effective Population Per Month	Average Daily Per Capita Consumption (gpcd)
Oct 77	2,535	298	284
Nov 77	2,049	253	270
Dec 77	3,795	207	611
Jan 78	11,141	161	2,307
Feb 78	12,248	257	1,589
Mar 78	9,131	312	976
Apr 78	10,399	1,213	286
May 78	13,991	1,397	334
Jun 78	21,369	10,276	69
Jul 78	22,730	13,502	56
Aug 78	10,880	5,000	73
Sep 78	5,130	238	718
Annual Total	120,268	---	---
Annual Average Daily Values	329,501 gal	2,760	631 gpcd

The annual average daily values for delivered water, effective population, and per capita consumption have been calculated and are shown in Table 19. Per capita consumption values are not given in the Redbook; only figures for the total annual water service and annual average daily effective population are shown. Computing a value based on annual average daily water service (total divided by 356 days) and annual average daily effective population results in a quite different estimation of per capita water service. This is shown by comparing the per capita values derived from the two methods:

$$\sum_{N}^{N=12} \frac{\text{Monthly Average Daily Per Capita Water Usage}}{12} = 631 \text{ gpcd} \qquad \text{[Eq 1]}$$

$$\frac{\text{Annual Average Daily Delivered Water}}{\text{Annual Average Daily Effective Population}} = \frac{329{,}501}{2760} = 119 \text{ gpcd} \qquad \text{[Eq 2]}$$

Eq 2 shows the problem of successively averaging daily effective population figures to arrive at a monthly average daily value, and then averaging the results to obtain an annual average daily value. In this example, it results in a gross underestimation of average daily per capita water use. Moreover, the 631 gpcd value does not reflect the broad range of monthly per capita values, which in this case, varies from a low of 56 gpcd (13,502 effective population) to a high of 2307 gpcd (161 effective population). This wide fluctuation in monthly population values would be rare among civilian communities, but is a frequent pattern on Army installations that serve as periodic training sites for Army Reserve and National Guard units.

A Test of Current Estimating Procedures

As a further test to determine the reliability of the FY 1981 Redbook effective population data, the average daily per capita water use values were calculated for each of the 90 installations by dividing a computed average daily water use quantity for the given installation by the effective population value. These values for 90 installations were used in a bivariate regression analysis, with effective population being the dependent variable. The mean value for the average daily per capita water use indicator was 242.04 gpcd, with a standard deviation of the mean at 349.67 gpcd and a standard error of the mean at 36.86.

The results of the analysis are:

$$\text{Average daily per capita water requirements} = \underset{(6.778)}{324.78} - \underset{(-2.591)}{0.006}\,(\text{effective population}) \qquad \text{[Eq 3]}$$

The values of the t-statistic are given in parentheses; both were significant below the 0.02 level. However, the coefficient of determination (R^2) was only 0.071, and the standard error of the estimate was 338.96 gpcd. The capability of this model to predict is obviously unacceptable. Installations with small populations would generally be overestimated. Also, the mean value of the estimated average day per capita water use is nearly one and one half times as large as the national average of 166.74 gpcd determined in a 1981 survey of water utilities by the American Water Works Association. The negative sign of he coefficient suggests that per capita water use is inversely related to the size of the effective population. The larger the effective population, the lower the value for per capita water use.

To adjust for this bias, designers of the current procedures for estimating average daily water use apparently "normalized" all per capita consumption values to 150 gpcd and introduced an adjustment factor, known as the capacity factor, into their estimating equation. Bandy and Scholze[15] investigated the derivation of this factor and its functional purpose. The capacity factor varies inversely with the magnitude of the population in the service area and is intended to allow for population increase, variations in water demand, uncertainties as to actual water requirements, and unusual peak demands. An effective population of 5000 or fewer would have a capacity factor of 1.5, while an installation with 50,000 or more persons would have a capacity factor value of 1.0.

[15] J. T. Bandy and R. J. Scholze, USA-CERL TR N-157, 1982.

Because the current procedures for estimating average daily water use are linked explicitly to effective population, it is reasonable to conclude that approximations of average daily water use would also be suspect. To test this conclusion, the procedures shown in Figure 3 were followed; the expected average daily water use for the 90 installations was calculated by multiplying the effective population values in the Fiscal Year 1981 Redbook by the appropriate capacity factor and a prescribed per capita daily allowance of 150 gal. Special-purpose quantities of water are not known for each installation and were assumed to be zero during the test. Because of this limitation, it was reasonable to expect that the estimates would be less than the actual average daily water use in the Redbook database. The Redbook data for water use is an aggregate measure and encompasses all water delivered throughout each installation.

The actual and estimated average daily water uses were then compared, anticipating that the latter value would be smaller than the actual value because special-purpose water had not been included in the computation. It was determined that 57 of the 90 installations (63 percent) had expected average uses greater than actual, indicating substantial overestimation (Figure 3).

An analysis of variance of the predicted and actual values for average daily water use was conducted to determine the coefficient of determination (R^2) and the standard error (SEE) of the estimate. The R^2 value was 0.564 and the SEE was 1.374 million gpd.

It is not possible to adjust the range of error in the estimated values without knowing the amount of special-purpose water; however, there is a lack of data because there are no meters for these activities. Moreover, for those installations already being overestimated, added special-purpose water would further exaggerate average daily water use approximations.

Collectively, the indicators observed from this assessment are sufficient to conclude that attempts to predict water use with any form of effective population (as it is presently calculated and shown in the Redbook database) would produce substantial error. A variety of procedures are practiced throughout the water industry. These methods are examined for application to Army installations in the following section.

Water Use Forecasting Methods in Civilian Communities

Water demand or requirement forecasting methods have improved greatly in the past 20 years. One way of categorizing these techniques is to separate them by the complexity of the variables extended into the model specifications. Single- and multiple-coefficient methods are discussed, and selected examples are critiqued from the perspective of compatibility with the existing Army database.

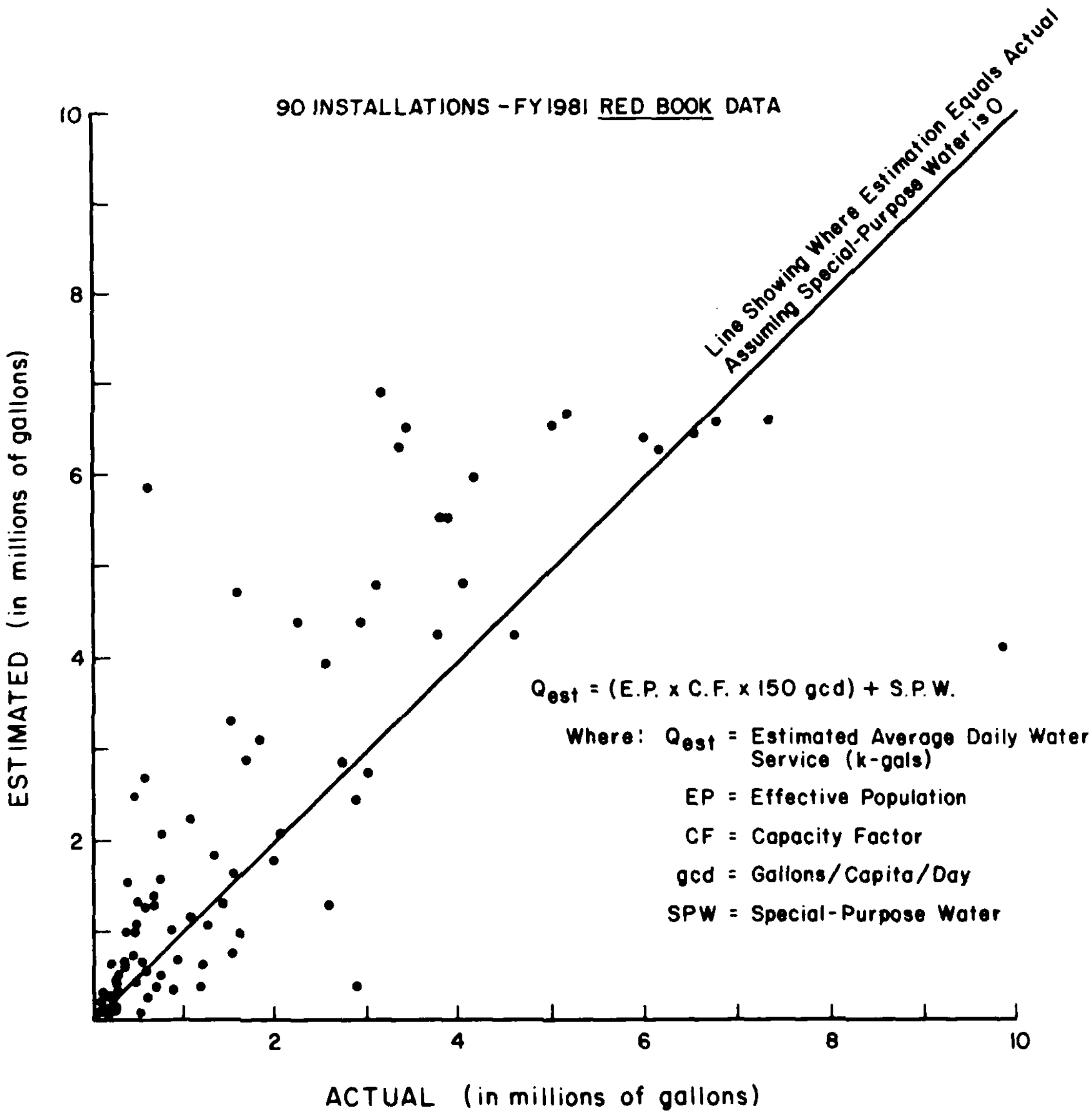

Figure 3. Comparison of actual vs. estimated average daily water service, applying current computational guidelines.

Single coefficient methods of estimating water use employ a single explanatory variable in the prediction model. Such models require data that would satisfy empirical analysis using these model forms; however, this data is not readily identifiable on Army installations. Unit use coefficient methods are frequently used to estimate commercial water use[16] and industrial water use.[17] In general, water use is forecasted as a function of the number of industrial employees or the number of households within the framework of a disaggregate forecast. Application on Army installations would require data on water use for commercial and industrial activities, and these data are not separable from total water service measurements.

Multiple coefficient methods use two or more explanatory variables as a mathematical function of future water use. The variables are chosen because of their past correlation to water use, and the functional form is selected to provide an acceptable fit to historic data. Water use models can usually be estimated by means of regression analysis from cross-sectional data representing simultaneous observations of water use and explanatory variables at a number of locations during a single time period.[18] The Redbook data for Fiscal Year 1981 exhibit these characteristics and provide the basis for testing a water requirements model.

Studies have shown that multiple coefficient requirements models perform well in predicting aggregate and sectoral water use. Studies were sought to determine if, among tested explanatory variables, building square footage and acreage were used to predict water use. A number of published reports show significant relationships between water use and area variables. Romm[19] argues that land use projections are more reliable than population projections for determining future water requirements. In a disaggregated projection for the Santa Clara Valley Water district, he estimates residential, industrial, and agricultural use as a function of subarea location, land area in acres, expected land use, and other inputs based on a master plan for the region.

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[16] A. C. Thompson, V. E. Smith, and W. R. Calvin, Development of Commerical Institutional Parameter Units for the MAIN II System of Water Demand Forecasting, OWRT Project C-6188 (Water Resources Research Institute, University of Wyoming, 1976); R. H. McCuen, R. C. Sutherland, and J. R. Kim, "Forecasting Urban Water Use: Commercial Establishmens," Journal of the American Water Works Association, Vol 67, No. 5 (May 1975), pp 239-244.

[17] J. C. Schaake, Jr., and D. C. Major, "Model for Estimating Regional Water Needs," Water Resources Research, Vol 8, No. 3 (June 1972), pp 755-759; Forecasting Municipal Water Requirements: Volumes I and II, the MAIN II System, Report No. HIT-413 (Hittman Associates, Inc., 1969).

[18] J. J. Boland, W. Moy, R. C. Steiner, and J. L. Pacey, Forecasting Municipal and Industrial Water Use: A Handbook of Methods, Report No. 83C-01 (Institute for Water Resources, U. S. Army Corps of Engineers, 1983).

[19] J. K. Romm, "Water Supply, Land Use, and Urban Growth," Journal of Water Resources Planning and Management Division, Proceedings of the American Society of Civil Engineers, Vol 103, No. WR2 (November 1977), pp 271-284.

Water use on Army installations can also be explained by grouped building areas analogous to the use of land areas for predicting water requirements. In this study, functional building gross area is analyzed in square feet, rather than in functional land areas. Although more detailed data, such as individual building areas and monthly quantities of water use, are maintained at the installation level, permission for its release would have to be obtained through the military chain of command. In this study, categorized total building areas are examined for variance differences in order to sum them into new composite variables that represent independent sectors of water use. Improved ground acreage and evapotranspiration are also empirically tested in the conceptualized model. Chapter 5 presents the details of this analysis.

Summary of Water Use Estimation Procedures Analysis

The measure of effective population, a key parameter in these procedures, is suspect due to the questionable weights applied to resident and non-resident groupings. The data representing effective population in the Redbook cannot be used to determine per capita average daily water use because of the way it is computed. The current procedures for estimating average daily water use were demonstrated and compared to actual water use values for the 90 installations in the study area. The results show that estimation is inaccurate and that predictions of future water requirements using this procedure would be unacceptable.

5 DATA STRUCTURE ANALYSIS AND MODEL DEVELOPMENT

This chapter examines an alternative approach to the Army's current procedural guidelines for estimating average daily installation water requirements. The alternative approach improves estimation and is acceptable as a prediction tool for forecasting future peacetime water requirements for the installations in the study area. The model was developed by analyzing the structure of cross-sectional data representing the gross square footage of categorized buildings on 90 installations. Water use sectors were identified and further tested to determine statistical relationships with average daily water use. The results of these tests and subsequent multivariate regression procedures are presented and interpreted.

The Model Framework

The generalized model to be used as a framework for this study takes the following form:

$$Q_{ad} = f\ (S_1,\ S_2\ .\ .\ .\ S_n,\ MD) \qquad \text{[Eq 4]}$$

where:

Q_{ad} = average daily installation water service in 1000 gal (k-gal)

and is a function (f) of:

$S_1\ .\ .\ .\ S_n$ = independent variables related to allocated building gross floor area in 1000 sq ft (k-sq ft) and representing sectors of water use.

MD = summer moisture deficit factor for total improved grounds area in acres, further defined as:

$$MD = TOIMPG\ (w_r - 0.6r_s)$$

where:

TOIMPG = total improved ground acreage per installation

w_r = summer average potential evapotranspiration rate

r_s = average summer precipitation rate.

Each sector is made up of one or more categories of buildings which will be identified by analyzing of the gross square footage of each category. Twelve types of areas encompass every building on any post where water use can occur. The moisture deficit factor accounts for outdoor irrigation or dust control water use and embodies the land area where water is used for this purpose. Conceptually, therefore, the model includes all areas on a given installation where water is delivered and used. Initially, the sectors may be considered to represent the commonly recognized residential, commercial, industrial, and institutional water use sectors.

In this analysis, it is critical that all 12 categories be included in the pending sectoral constructs to assimilate the total post real property where water use occurs. Exclusion of a single category would suggest that it has no relationship to installation water service, but there is no evidence to support such conclusions. Also, category rejection would weaken the combined sector array and imply incomplete final model specification. Although the model developed herein is intended to be used for prediction, it must actually provide for a reasonable explanation of water service as a complete composite of various sectors of water-using activities.

Categories of buildings range from family housing structures to research and development buildings, with all areas measured in units of 1000 sq ft and with nonoverlapping category contents. The Redbook provides gross floor area measurements of every building category on each installation in thousands of square feet. This accounting is based on a uniform construction category coding system established by Army Regulation and applies to every installation in the Army. Table 20 shows the general categories of building areas as independent variables 1 through 12. Because of the uniform coding system, the Army can keep an accurate inventory and control of all facilities in a compatible manner. Each category is independent of all others regarding the content of the types of buildings it contains. The following sections discuss each category and its expected effect on water service.

Family Housing

This category represents all buildings used as or in conjunction with family quarters, including attached private garages and detached appurtenant structures such as garages, adjacent storage sheds, laundry rooms, and incinerators. The types of housing include single-family residences and multiple-family permanent dwellings. Water service for domestic water uses is expected to increase as buildings are added in this category.

Bachelor Soldier Quarters

Housing for unaccompanied personnel (without on-station family) is provided by barracks, dormitories, and other similar facilities with or without dining (kitchen) facilities. This category also includes detached dining facilities where soldiers and civilians regularly have their meals as a group and day rooms (lounge and game rooms). Water-using activities are for personal hygiene, but would also satisfy water requirements associated with large mess halls, which are comparable to commercial cafeterias of the same size.

Table 20

List of Variables and Their Designations

No.	Symbol	Variable Definition	Unit
	Dependent Variable:		
1	Q_{ad}	Average daily water service	k-gal
	Independent Variable:		
1	FAMBLD	Family housing gross floor area	k-sq ft
2	BACBLD	Bachelor housing gross floor area	k-sq ft
3	TRABLD	Training buildings gross floor area	
4	COMBLD	Community buildings gross floor area	k-sq ft
5	MEDBLD	Medical buildings gross floor area	k-sq ft
6	OPSBLD	Operations buildings gross floor area	k-sq ft
7	MNTBLD	Maintenance and production buildings gross floor area	k-sq ft
8	STOBLD	Storage buildings gross floor area	k-sq ft
9	RDTBLD	Research, development, and test buildings gross floor area	k-sq ft
10	UTPBLD	Utility plants gross floor area	k-sq ft
11	ADMBLD	Administration buildings gross floor area	k-sq ft
12	OTHBLD	Other buildings gross floor area	k-sq ft
13	MDEFICIT	Average moisture deficit factor	in./acres/ summer

Water service would increase commensurate with an expansion of the facilities in this category. Laundry facilities are generally centrally located in dormitories for common use by building residents; however, they may prefer to use laundromats elsewhere.

Training

Classrooms and other special buildings where instruction is given make up this category and would cover structures on training courses, ranges, and maneuver areas. Water is required for drinking and sanitary purposes; service to these buildings would increase as new structures are added or existing facilities expanded.

Community Service

Buildings in this category provide for the support and service of installation personnel and their morale, welfare, and indoor recreation needs. The structures extend across a broad range of public and commercial support activities, including fire stations, guard and police stations, bus or ticket stations, post office, chapels, laundry and dry cleaning plant, bakery and nursery, and elementary and secondary schools. Indoor athletic and recreational activities and retail outlets are also in this category. Typical buildings are bowling alleys, field houses, gymnasiums, and indoor swimming pools; banks, service personnel clubs, and open restaurants; theaters and auditoriums, recreational and entertainment workshops, and craft centers; AAFES main and branch exchanges, concessions, and gas stations; and Red Cross and YMCA centers. Water requirements for these activities would not be unlike those of a civilian community and would increase as more structures are added.

Medical

These buildings support both in-patient and out-patient hospital and medical center support, as well as triage, clinical, and medical dispensary facilities for soldiers and their families. Dental clinics and veterinary facilities are included, but medical research, development, and testing (RD&T) buildings are assigned to the RD&T building category. Water is used for patient services and for medical hygienic and operational requirements, and it is reasonably assumed that facilities with larger floor areas will generally support greater numbers of patients and would need complementary increments of water.

Operations

This category of buildings is dominated by military mission-related activities, such as communication structures for radio, radar, relay, and telephone operational networks. Typical examples are operational readiness facilities, such as alert hangars, operations, and fire and rescue stations at airfield and missile war-heading and launching structures. Reception station processing facilities are also assigned to this category. Compared to other categories, water service to support these activities is assumed to be small, both in water quality and in total category building area; however, this would increase to correspond with building growth and new construction.

Maintenance and Production

Maintenance activities encompass facilities and shops for the maintenance, repair, and overhaul of all military equipment and installation real property. It also includes plants for constructing and assembling military supplies, including ammunition. This category reflects mission-oriented activities and is like manufacturing establishments in civilian communities. Water use for industrial processing may be quite large, depending on the product. Water service and maintenance and production facilities are directly related, and changes in building areas can be assumed to be matched by complementary changes in water requirements.

Storage

Water service is minimal for activities that describe the buildings in this category. Water is used for custodial functions, if any, and to arm fire-sprinkling systems. Ammunition storage structures and warehouses are the principal building types in this category. It is assumed that activities represented by storage facilities exert a weak influence on water service and would not explain or predict major quantities of average daily water service. An increase in the total gross floor area of storage facilities on installations with dedicated depot missions is likely to raise water service requirements to support fire-fighting operations if all other water-using activities remain constant.

Research, Development, and Test (RD&T)

These buildings are used directly in theoretical or applied research operations. Basic research laboratories for areas such as chemistry, materials, medical, biological, sonic, physics, and geophysics are contained in this category, as well as development and test facilities related to this research. Water service to support these activities is expected to be high, especially on installations having substantial building areas for RD&T.

Utility Plants

Cold storage freeze and chilled water for air-conditioning plants and cold and refrigerated warehouses are in the utility plant category. Also included are buildings associated with electric power generation or transmission heating or power plant generation equipment for temperature-controlled water or pressure-regulated steam, municipal sewage and industrial waste treatment, and disposal structures, nonpotable and potable water supply (wells), and treatment and storage tanks. Water is generally an integral component of the activities associated with these buildings, and it is expected that the larger the gross floor area, the greater will be the average daily water use.

Administration

Buildings within this category include headquarters and office-type buildings for civilian and military personnel administration, automatic data processing, and technical libraries. Water is required for sanitary, custodial, and fire-extinguishing systems. Again, water service would tend to increase with an increase in gross floor area.

Other

This category includes all buildings not designated within the previous 11 categories. Examples are limited because of their comprehensiveness; however, museums and covered grandstands and bleachers are samples. Water use is minimal and contributes to only a small fraction of average daily water use.

Moisture Deficit

Installation water use may also be influenced by the amount of sprinkling water applied to irrigable areas. With precipitation and evapotranspiration accounted for, Howe and Linaweaver[20] defined this influence as summer potential evaporation in inches minus 60 percent of the summer precipitation in inches. Hittman Associates, Inc.[21] incorporated this measure in the MAIN II System for forecasting municipal water requirements and determined values from interpolations of summer potential evapotranspiration and precipitation contour maps. The latter technique was used for this study.

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[20] C. W. Howe and F. P. Linaweaver, "The Impact of Price on Residential Water Demand and Its Relation to System Design and Price Structure," Water Resources Research, Vol 3, No. 1 (First Quarter) (1967), pp 13-32.

[21] Forecasting Municipal Water Requirements: Volume I and II, the MAIN II System, 1969).

The 60 percent factor formulated by Howe[22] as noted above represents the effective fraction of average summer rainfall penetrating to the vegetative root zone. The outdoor irrigable area is represented by total improved grounds measured in acres.

Statistical Analysis of the Data Structure and Final Model Specification

Because of the large number of independent building categories being analyzed, criteria had to be set for selecting groups of categories to represent water service sectors. These sectors are the final explanatory variables in the conceptualized general model. Substantial high multicollinearity among the building category variables required a strategy to reduce them to an acceptable level where regression coefficient estimates would not be adversely affected. Appendix C describes the results of various statistical analyses applied during the stages of model development. The statistical analysis involved systematically determining which categories of building use could be grouped to form sectors. The resulting sectors include the following building categories:

- Community Service and Support Sector
- Military Activities Sector
- Research and Post Utility Support Sector

These sectors became the independent variables in the linear additive model of the form:

$$Q_{ad} = a + b_1 \text{(COMMUN)} + b_2 \text{(MILACT)} + b_3 \text{(RDTUTIL)} + b_4 \text{(MDEFICIT)} + e \quad \text{[Eq 5]}$$

where:

Q_{ad} = average daily installation water use in k-gal

$b_1 \ldots b_4$ = coefficients of the corresponding independent sector variables

COMMUN = community service and support sector in k-sq ft

MILACT = military activity sector in k-sq ft

RDTUTIL = research and post utility support sector in k-sq ft

MDEFICIT = moisture deficit factor (as defined in the conceptualized model)

[22]C. W. Howe, "The Impact of Price on Residential Water Demand: Some New Insights," Water Resources Research, Vol 18, No. 4 (August 1982), pp 713-716.

a = constant term

e = error term.

This water use model was tested with actual data from the installations and then subjected to regression analysis to refine the coefficients. The final best fit equation, based on the community service, military activity, and research and post utility support sectors is:

$$Q_{ad} = 0.339 \text{ COMMUN} + 0.079 \text{ MILACT} + 0.754 \text{ RDTBLD} \qquad \text{[Eq 6]}$$

The constant term was eliminated from the model because it was statistically shown to be not significantly different from zero. The moisture deficit factor did not help explain average daily water use and is not included; however, it could be incorporated if summer seasonal water use data were available to test the model.

Interpreting the parameter estimates of the best fit equation is straight forward. For example, a one-unit (1000 sq ft) increase in the building floor area of the community service sector would produce a 339-gpd increase in average water service. It is reasonable to expect a family housing unit of 1500 sq ft to cause an increase of 496.5 gal. This increase would suggest a 165.5 gpcd for a family of three. Similarly, a one-unit increase in the gross square footage of buildings in the research and post utility support sector would correspondingly increase average daily water service by 754 gal. The coefficient for the military activity sector can be interpreted in the same way: average water use will increase by 79 gpd for a one-unit increase in the buildings within this sector.

The sector coefficients may also be used to provide a rough measure of disaggregated water use for evaluating potential water conservation measures. For example, water use in bachelor housing may be approximated by the product of the total building area in this category on a given installation and the coefficient value of 0.339 for the community service sector. The resultant quantity of water could be used as the representative average daily use in order to estimate the effectiveness of a conservation measure being considered. The expected fractional reduction in water use and the expected degree to which the measure were implemented would also be required to complete an effectiveness evaluation.

The standard error of estimate in the equation represents the unexplained variance of the dependent variable. The proportion of cases that fall between ± 1 standard error of the estimate was determined to be 77.8 percent (69 of 89 cases). Reduction in standard error may be possible if the value of average daily water use is adjusted to account for leaks in the distribution system. This would tend to improve underestimated values at installations where water losses of this type occur. Water sold to off-post customers, if any, may also improve low-sided estimates if such sale quantities were deleted from the value of the dependent variable. In general, average daily water use is a weak measure of water service and requires further disaggregation into monthly or seasonal values in order to reassess the moisture deficit factor and potentially reduce error.

Comparing Procedures: Current Guidelines Versus Requirement Model

Figure 4 is a plot of the actual versus estimated values of average daily water use. It can be contrasted with Figure 3, which duplicates the values obtained by applying current Army procedural guidelines for estimating the same dependent variable. It is clear that the requirement model presents a better estimation and prediction procedure. The linear additive model developed here has improved the power of prediction. Current Army procedures yield an R^2 value of 0.564, compared to 0.873 for the model. The standard error of the estimate has been reduced by 50 percent--from 1374 to 690 k-gal per day. Appendix D provides estimated values for each installation using both procedures. Although the model provides substantial improvement, it predicts only average daily water use, and requires additional evaluation with data representing summer and winter water use.

Model Application to Water Use Planning

The results of the analysis and investigative procedures support the general conclusion that it is possible to identify independent sectors of water use by grouping specific building categories. Although limited in scope, the analysis showed three statistically significant sectors of water use: a community service and support sector, a military activity sector, and a research and post utility support sector. When empirical data representing these sectors were tested within a conceptualized linear additive model, the results explained 87 percent of the variance of average daily water use. A moisture deficit factor failed to meet statistical criteria for inclusion in the best fit model; however, it was shown to be positively related to average daily use.

The model would be of great utility to installation planners. It not only outperforms existing procedures, but also facilitates the evaluation of potential conservation measures for specific water use sectors. It could also be used to determine which installations are using more water than the amount expected as estimated by the model.

Ideally, the technique can be operationalized as a module into the computerized Integrated Facilities System available to Engineering and Housing Directorates. A user-friendly manual would make application straightforward and result in timely estimates and forecasting of water requirements. The empirical data required to use the model is readily available to all installation Facility Engineers. With knowledge of expected future construction or destruction of buildings, the impact on average daily water service can be forecasted and evaluated in accordance with the model specifications.

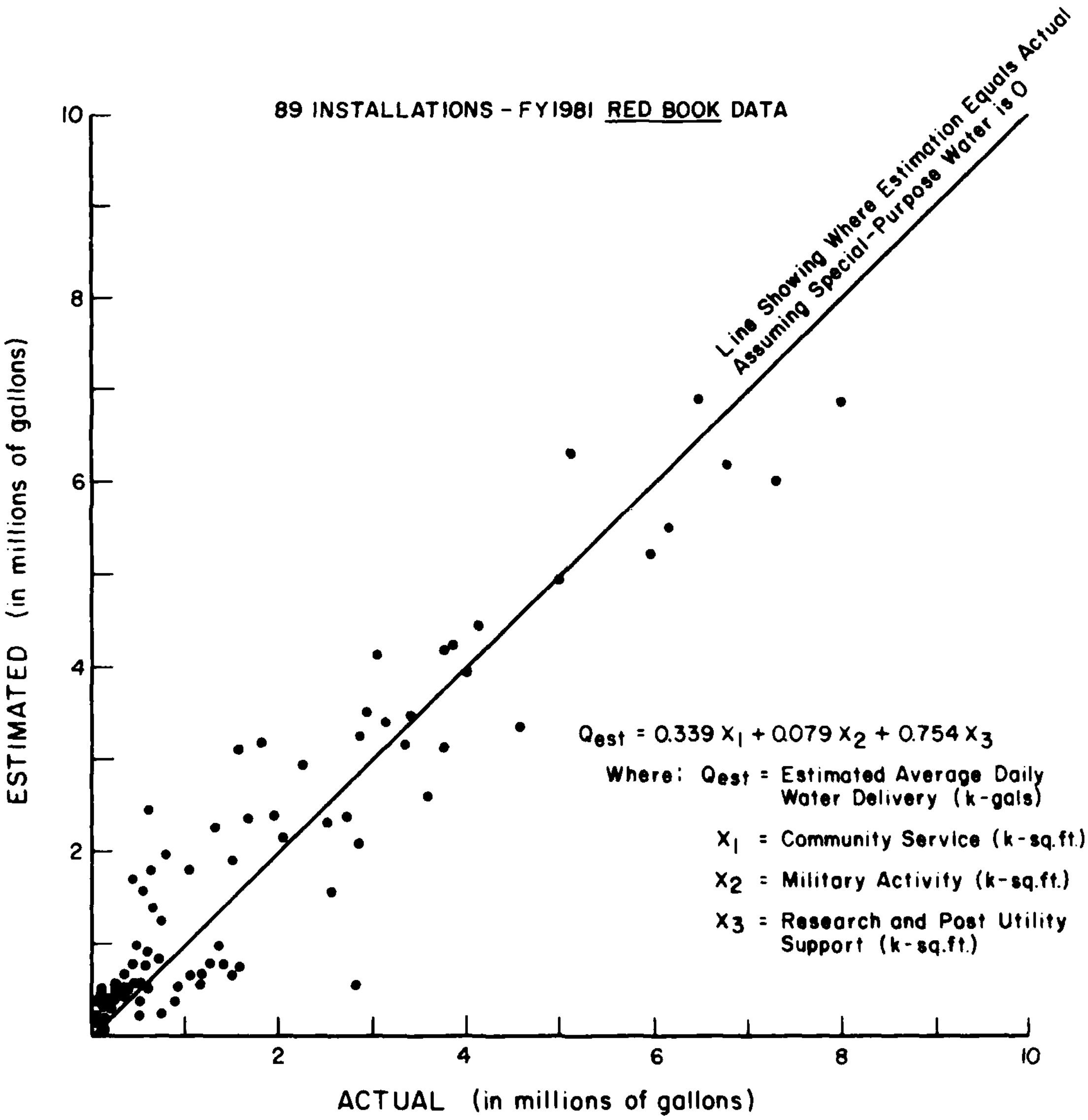

Figure 4. Comparison of actual vs. estimated average daily water service applying revised linear additive model without outlier (Redstone Arsenal).

6 CONCLUSIONS

More than one third of the installations surveyed in this study did not know what quantities of water would be needed to support Fiscal Year 1990 requirements. Even among those posts which adjudged a general direction in future water needs, only about one fourth of the reporting stations have apparently evaluated water needs for the future using a method that goes beyond judgmental planning. However, the 22 water use forecasts that have been done are based on a per capita or an adjusted per capita approach, which does not facilitate evaluation of water conservation measures.

There is no formal water conservation policy for Army installations; as a result, 55 (64 percent) of the surveyed installations indicate they have not implemented a water conservation program within the past 5 years. Moreover, the types of conservation measures being executed are limited primarily to irrigation restrictions and reduced-flow plumbing fixtures, and in most instances, the benefits or costs of implementing these measures have not been quantified. A mandated water conservation policy would probably stimulate a broadened water planning effort; however, procedural guidelines are needed to help installation planners evaluate potentially adaptable and socially acceptable conservation actions.

Major discrepancies are apparent within current Army procedures for estimating average daily water demand. The measure of effective population, a key parameter in these procedures, is suspect due to the questionable weights applied to resident and nonresident groupings. The data representing effective population in the Redbook cannot be used to determine per capita average daily water use because of errors in the way it is computed. The current method of estimating average daily water use using effective population data is unreliable; therefore, attempts to predict future water use using this procedure would be unacceptable.

The linear additive model, which uses categorized building areas (data readily available to installation Facility Engineers) to predict sectors of water use, effectively predicts peacetime water needs. This model could also be used to evaluate the effectiveness of conservation measures and to determine whether an installation should be considered for a water use survey.

Documented contingency plans are more likely to be found on FORSCOM and TRADOC installations than on AMC posts, where single sources of water supply prevail. Most installations (59 percent) indicated they had no contingency plans prepared, which reflects a need to increase planning emphasis in this area.

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APPENDIX A:

THE MAIL SURVEY

WATER SUPPLY AND USAGE ON US ARMY FIXED INSTALLATIONS

The following questions refer to various characteristics of the water supplied and used on US Army installations located within the contiguous United States. Your thoughtful consideration in responding to this information request will contribute in determining an Army-wide characterization and analysis of DEH/FE planning and operations of military community water supplies. Your response, along with others, will assist in this study to find out the role of water use forecasting and water conservation in DEH/FE planning, as well as the need, if any, for improved guidance and procedures.

I shall be very appreciative if you would complete the attached questionnaire and mail it to me in the self-addressed, stamped envelope by 25 January 1984. Thank you for your cooperation.

IF YOU HAVE ANY QUESTIONS, PLEASE CALL LTC JOHN LANGOWSKI

AT (618) 536-3375 BETWEEN 0900 - 1600 HOURS, CST

1. Please complete the following table to show the fiscal year total effective population for your installation and the total fiscal year quantity of water in 1000 gallon (k-gallon) units required from each of the listed sources of water supply.

	Total Effective Population	Total Purchased Water	Total Self-Supplied from Surface Sources	Total Self-Supplied from Wells
FY 1982	____ persons	____ k-gallons	____ k-gallons	____ k-gallons
FY 1983	____ persons	____ k-gallons	____ k-gallons	____ k-gallons
Projected for FY 1990 (please check)	____ increase ____ decrease ____ remain about the same as FY 1983 ____ don't know	____ increase ____ decrease ____ remain about the same as FY 1983 ____ don't know	____ increase ____ decrease ____ remain about the same as FY 1983 ____ don't know	____ increase ____ decrease ____ remain about the same as FY 1983 ____ don't know

2. Communities or other activities outside of your installation may be receiving some amount of water supply from post facilities:

a. Does your installation provide water to off-post customers? (Please check)

_______ No. Water is not being furnished to off-post customers through installation facilities. (If you checked this answer, go to Question 3.)

_______ Yes, but only in the event of an emergency requirement and the type of water being supplied is (please check):

_______ raw water _______ treated water _______ both

_______ Yes, on a regular interval basis and the type of water being supplied is (please check):

_______ raw water _______ treated water _______ both

b. Indicate the total annual quantity of water (in k-gallons) supplied to off-post customers:

FY 1982	_______ k-gallons or _______ data not available
FY 1983	_______ k-gallons or _______ data not available
Projected for FY 1990	_______ k-gallons or _______ data not available

c. Indicate how often and for what reasons water is supplied or is to be supplied to off-post customers:

	Number of Days per Fiscal Year	Reasons(s) for Providing Off-post Water Service
FY 1982		
FY 1983		
Projected for FY 1990		

3. Please check the applicable box(s) that indicate the type of meter currently in place for each of the following water user categories: (If none, then write NONE)

Category of Water User	Individual Connection Meter (please check)	Sub-area Master Meter (please check)	Installation Master (Meter) (please check)
Temporary/Transient Quarters			
Family Housing			
Bachelor Soldier Quarters			
Main/Branch Post Exchange			
Commissary			
Bank			
Post Office			
Credit Union			
AAFES Gas Station(s)			
AAFES Laundromats			
AAFES Cafeterias/Restaurants			
Main Clubs/Annexes			
Soldier Dining Facilities			
Gymnasiums			
Swimming Pools			
Other Indoor Recreational Activities (please specify)			
Hospitals			
Medical Clinics			
Dependent Schools			
Military Vehicle Wash Facilities			
Military Laundry/Dry Cleaning			
Military Vehicle Maintenance			
R & D Laboratories			
Boilers and Steam Generation			
Metal Cleaning & Plating			
Cooling Towers & Wet Scrubbers			
Administration Offices			
Command-level Headquarters			
Soldier Instructional Facilities			
Communications Facilities			
Landscape Irrigation			
Air Terminal Operations			
Emergency Fire Water			
Off-post Customers			
Other Categories not listed above (Please specify)			

4. a. Do any of the above categories of water users listed in Question 3 pay directly in dollar charges (not as a housing allowance) for their water service? (Please check)

Yes ________ No ________ (If you checked No, go on to Question 5.)

b. If you checked yes, please list the specific water user categories and the billing period interval.

Customer Category	Billing Frequency

5. Has there been a study done within the past 5 years that has included a *forecast of future water needs* for your installation?

________ Yes. (Please include a copy of this study and any others which analyze water use forecasts or patterns on your installation. Send them along with this completed questionnaire.)

________ No. (If you checked this answer, go on to Question 12.)

QUESTIONS	ANSWERS Study No. 1	 Study No. 2	 Study No. 3
6. What recent studies (last 5 years) of your installation included water use forecasts? (Please name only one study for each box)			
7. For each study, who performed the water use forecasts? (Please check)	Corps District Personnel ____ Consultant to Corps District ____ DEH/FE In-house Personnel ____ Consultant to DEH/FE ____	Corps District Personnel ____ Consultant to Corps District ____ DEH/FE In-house Personnel ____ Consultant to DEH/FE ____	Corps District Personnel ____ Consultant to Corps District ____ DEH/FE In-house Personnel ____ Consultant to DEH/FE ____
8. For each study, what was the forecast period? Please identify the <u>base</u> year and the <u>last</u> year or other time increment.	Base year ________ Last year ________ Other time increment: Base unit ________ Last unit ________	Base year ________ Last year ________ Other time increment: Base unit ________ Last unit ________	Base year ________ Last year ________ Other time increment: Base unit ________ Last unit ________
9. What was the forecast unit or units? (Please check)	Annual water use ________ Average day water use ________ Maximum day water use ________ Seasonal water use ________ Maximum month water use ________ Other: ________ (Briefly describe on separate sheet)	Annual water use ________ Average day water use ________ Maximum day water use ________ Seasonal water use ________ Maximum month water use ________ Other: (Briefly describe on separate sheet)	Annual water use ________ Average day water use ________ Maximum day water use ________ Seasonal water use ________ Maximum month water use ________ Other: ________ (Briefly describe on separate sheet)
10. What types of water use were forecasted?	Total water use ____ Family Housing water use ____ Commercial water use ____ Industrial water use ____ Irrigation water use ____ Leaks & unaccounted water use ____ Mobilization water use ____	Total water use ____ Family Housing water use ____ Commercial water use ____ Industrial water use ____ Irrigation water use ____ Leaks & unaccounted water use ____ Mobilization water use ____	Total water use ____ Family Housing water use ____ Commercial water use ____ Industrial water use ____ Irrigation water use ____ Leaks & unaccounted water use ____ Mobilization water use ____
11. What method(s) were used to make the forecast?	Population times per capita use ____ Effective population adjusted by a capacity factor, then times per capita use ____ Statistical Analytical Method ____ Judgment method based on opinions of DEH/FE personnel ____ Other ____ (Briefly describe on separate sheet)	Population times per capita use ____ Effective population adjusted by a capacity factor, then times per capita use ____ Statistical Analytical Method ____ Judgment method based on opinions of DEH/FE personnel ____ Other ____ (Briefly describe on separate sheet)	Population times per capita use ____ Effective population adjusted by a capacity factor, then times per capita use ____ Statistical Analytical Method ____ Judgment method based on opinions of DEH/FE personnel ____ Other (Briefly describe on separate sheet)

12. a. Please place a check next to those potential short-term water shortages for which your installation has prepared written contingency plans:

_____ There are no documented plans at present. (If you checked this answer, please go on to Question 13.)

_____ Drought conditions

_____ Mobilization requirements

_____ Contaminated water quality

_____ Other (Please describe) ______________________________

____

b. Which specific water conservation measures are included in the above water shortage contingency plans? Please list each measure separately in the space below:

____

____

____

____

____

____

13. Has your installation implemented a water conservation program within the past 5 years?

Yes__________ No__________ (If you checked NO FOR this answer, please go on to Question 17.)

QUESTIONS	ANSWERS		
	Water Conservation Measure #1	Water Conservation Measure #2	Water Conservation Measure #3
14. Please name one specific water conservation measure in each of the boxes which has been used on your installation in the past five years.			
15. Briefly describe the reasons for selecting this particular measure.			
16. Briefly describe the results of using this conservation measure.			

17. Please fill in the requested information:

Your job title ____________________

Years in this position ______________

Point of Contact for follow-up information:

Name: ____________________________

Telephone Number ____________________
(Commercial)

PLEASE PLACE THIS QUESTIONNAIRE AND A COPY OF THOSE STUDIES WHICH ANALYZE WATER USE FORECASTS OR PATTERNS ON YOUR INSTALLATION IN THE ATTACHED PRE-ADDRESSED STAMPED ENVELOPE AND MAIL WITHOUT DELAY.

THANK YOU FOR YOUR THOUGHTFUL CONSIDERATION TO THE ABOVE QUESTIONS.

APPENDIX B:

SUMMARY TABULATION OF WATER-RELATED PLANNING INDICATORS

The following table summarizes the responses obtained from the 1984 Survey of Water Use on Army Installations that pertain to the status of prepared documents or implemented programs concerning water requirement forecasts, water shortage contingency plans and water conservation programs. The table is intended to provide Army planners with an overview of Major Command activities related to water planning on eighty-five installations in the contiguous United States. The presence of a water conservation program indicates that one or more conservation measures have been implemented on an installation within the past five years. The entries represent the number of installations in each category; the numbers in parentheses are corresponding column or row percentages.

Planning Status	MAJOR COMMAND									TOTALS
	FORSCOM	TRADOC	DARCOM	USACC	HSC	INSCOM	MTMC	USMA	MDW	N (%)
Water Requirement Forecast Only	1	2	4	--	--	--	1	--	--	8 (9.4)
Water Shortage Contingency Plan Only	2	4	4	--	--	--	--	--	1	11 (12.9)
Water Conservation Program Only	7	3	1	--	--	--	--	--	--	11 (12.9)
Forecast and Shortage Contingency Plan	--	1	2	1	--	--	--	--	--	4 (4.7)
Forecast and Water Conservation Program	2	2	1	1	--	--	--	--	--	6 (7.1)
Shortage Contingency Plan and Water Conservation Program	2	1	2	--	2	--	2	1	--	10 (11.8)
All Three Planning Indicators	3	3	--	--	--	--	--	--	--	6 (7.1)
None of the Above	3	1	19	--	1	2	1	--	2	29 (34.1)
TOTALS	20 (23.5)	17 (20.0)	33 (38.8)	2 (2.4)	3 (3.5)	2 (2.4)	4 (4.7)	1 (1.2)	3 (3.5)	85 (100)

APPENDIX C:

STATISTICAL ANALYSIS OF THE DATA STRUCTURE AND MODEL DEVELOPMENT

Linearity Characteristics

The first step in the data analysis was to examine the general statistics describing distribution of the 90 installations for each building category and evaluate the linear relationship of each category variable with average daily water use (Q_{ad}). Three measures are associated with simple linear regression: the Pearson product moment correlation coefficient, its test of significance, and the slope. Table C1 presents the values of these measures and other related statistical measures. The first measure--the correlation coefficient--represents the zero-order correlation between the pair of variables; no controls for the influence of other variables are made. This coefficient is used to measure the strength of relationship in terms of goodness of fit of a linear regression line to the data. The test of significance of the correlation coefficient is derived from Student's t, and the reported value indicates the results of testing and hypothesis that the coefficient is not significantly different from zero. The slope estimate indicates the average change in Q_{ad} that is associated with a unit change in the respective building category variable.

Among the building category variables, correlation coefficients range from a high value of 0.838 for family housing to an extremely low value of -0.048 for storage buildings. The scattergram depiction of plotted values of this latter variable with average daily water use (Q_{ad}) indicated outlier values representing high quantities of average daily water use and low gross floor area for storage buildings, which created an upward bias in this region in the regression slope and a weak correlation coefficient. The result of this effect is to force an inverse relationship between the paired variables, as noted by the negative signs for both measures. The slope for the variable is very small compared to other building variables with a similar range of values, such as bachelor buildings at 0.863. The category of "other" buildings also displayed a plot of paired values with outlier values representing low quantities of water use and high values of gross floor area in this category. The bias is downward and also results in an unreliable regression coefficient.

Rather than remove the outliers at this point in the analysis, they were retained for further examination and were transformed by grouping with sister categories to form new independent variables. Moreover, the outlier values differed between the storage and other building categories; complete withdrawal would cause the loss of considerable information regarding the relationship of water use with the remaining categories of buildings that these outliers possessed.

Table C1

Statistical Characteristics of the Variables*

Variable Code	High Value	Low Value	Mean	Standard Deviation	Correlation Coefficient**	Correlation Significance	Bivariate Regression Slope	Slope Significance***
Q_{ad}	9847	11	1813	2080	--	--	--	--
FAMBLD	8294	0	1444	2019	.838	.0001	.863	.0001
BACBLD	7704	0	1347	1885	.772	.0001	.852	.0001
TRABLD	2574	0	446	566	.594	.001	2.183	.0001
COMBLD	1937	0	481	501	.809	.0001	3.357	.0001
MEDBLD	2848	0	211	366	.441	.0001	2.507	.0001
OPSBLD	1008	0	147	191	.424	.0001	4.622	.0001
MNTBLD	2303	0	563	519	.576	.0001	2.306	.0001
STOBLD	7740	0	1431	1690	-.048	.3263	-0.059	.6526
RDTBLD	2352	0	139	358	.225	.0164	1.309	.0329
UTPBLD	255	0	54	46	.588	.0001	26.743	.0001
ADMBLD	1964	4	435	391	.570	.0001	3.035	.0001
OTHBLD	620	8	42	110	.143	.0893	2.698	.1787
MDEFICIT	382706	-1280	40956	55836	.586	.0001	0.022	.0001

*Values are for 90 cases.
**Person's r for paired variables consisting of Q_{ad} and the given variable.
***Significance determined by two-tailed t-test.

The other 10 categories of buildings showed data structures with highly significant correlation coefficients as well as regression coefficients. The moisture deficit factor is also shown as equally significant by both measures.

Average daily water use requires a fuller explanation than that offered by the separate single categories of buildings. It has been postulated that it is a function of all the building areas combined. Multiple regression facilitates the analysis of the combined effects of all independent variables, assuming that they are not perfectly correlated with one another.

Initial Multiple Regression Analysis

A preliminary multiple regression analysis was performed in which average daily water use was regressed on all 13 independent variables (Table C2). The partial coefficients for family housing, bachelor soldier quarters, and research buildings are significant below the criterion level of .05 based on a two-tailed t-test. All other independent variable coefficients are statistically insignificant, indicating that each failed to reject the null hypothesis that their values were not different from zero. Yet the R^2 for the equation is substantial at 0.809. Lewis-Beck[23] reports this type of condition as a rather sure symptom of high multicollinearity.

Although independent variables are virtually always intercorrelated, high multicollinearity is a condition in which one independent variable approaches a perfect linear functional relationship with another independent variable. If this condition is present, the consequence is that serious parameter estimation problems arise, causing them to be unreliable. There can be little confidence that a particular slope estimate accurately reflects the impact of the independent variable on average daily water use.

Bivariate correlations were computed for each independent variable with all others (Table C3). The matrix shows that the correlation coefficients between family housing, bachelor buildings, and community buildings are high at 0.856, 0.875, and 0.891, respectively. Coefficients greater than 0.7 exist between training and bachelor buildings (0.730) and between training and community buildings (0.763).

Although these high values suggest the presence of high multicollinearity among these variables, particularly those in excess of 0.8, the correlation matrix does not account for the relationship of one independent variable with all the other independent variables. It is possible that one independent variable may be a nearly perfect linear combination of the remaining independent variables, even though the bivariate correlation coefficients are not large. The method for assessing this potential hidden condition is to

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[23] M. S. Lewis-Beck, Applied Regression, Sage University Paper Series on Quantitative Applications in the Social Sciences 07-022 (Sage Publications, 1980).

Table C2

Initial Multiple Regression Analysis
(Dependent Variable: Average Daily Water in k-gal)

Independent Variable	Partial Coefficient	t-Value	Significance of t
FAMBLD	0.399	2.889	0.005
BACBLD	0.337	2.12	0.030
TRABLD	-0.324	-1.030	0.306
COMBLD	1.023	1.453	0.150
MEDBLD	0.188	0.477	0.635
OPSBLD	0.158	0.220	0.827
MNTBLD	0.243	0.682	0.497
STOBLD	0.063	0.828	0.410
RDTBLD	1.616	4.345	<0.001
UTPBLD	-2.292	-0.611	0.543
ADMBLD	0.569	1.504	0.137
OTHBLD	-1.034	-0.858	0.394
MDEFICIT	-0.002	-0.800	0.462
(Constant Term)	-61.559	-0.323	0.747

Coefficient of Multiple Determination (R^2 = .809)
Standard Error of the Estimate = 976 k-gal
F-Ratio = 24.822
Degrees of Freedom = 13 and 76
F-Significance = <.0001

Table C3

Bivariate Correlation Matrix Between Pairs of Variables

	TRABLD	MNTBLD	POTBLD	MEDBLD	ADMBLD	RACBLD	COMBLD	FAMBLD	OPSBLD	UTFBLD	OTHBLD	STOBLD	MDEFICIT
TRABLD	1.000	0.400	0.012	0.380	0.506	0.730	0.763	0.650	0.309	0.475	0.282	-0.220	0.443
MNTBLD	0.400	1.000	-0.075	0.218	0.375	0.613	0.570	0.615	0.579	0.501	0.039	0.313	0.620
BPTBLD	0.012	-0.075	1.000	0.038	0.242	-0.133	-0.027	-0.014	-0.070	0.342	0.048	0.030	0.043
MEDBLD	0.380	0.218	0.038	1.000	0.360	0.483	0.519	0.441	0.219	0.334	0.518	-0.181	0.250
ADMBLD	0.506	0.375	0.242	0.369	1.000	0.406	0.571	0.502	0.172	0.521	0.174	-0.074	0.255
BACBLD	0.730	0.613	-0.133	0.483	0.406	1.000	0.875	0.865	0.486	0.496	0.192	-0.163	0.668
COMBLD	0.763	0.570	-0.027	0.519	0.571	0.875	1.000	0.891	0.437	0.641	0.301	-0.129	0.612
FAMBLD	0.650	0.615	-0.014	0.441	0.502	0.865	0.891	1.000	0.455	0.526	0.154	-0.137	0.661
OPSBLD	0.309	0.579	-0.070	0.219	0.172	0.486	0.437	0.455	1.000	0.378	-0.061	0.197	0.494
UTFBLD	0.475	0.501	0.342	0.334	0.521	0.496	0.641	0.526	0.378	1.000	0.204	0.076	0.369
OTHBLD	0.292	0.939	0.084	0.518	0.174	0.192	0.301	0.154	-0.061	0.204	1.000	-0.160	0.025
STOBLD	-0.220	0.313	0.030	-0.181	-0.074	-0.163	-0.129	-0.137	0.197	0.976	-0.160	1.000	0.099
MDEFICIT	0.443	0.620	0.043	0.250	0.255	0.668	0.612	0.661	0.494	0.369	0.925	0.099	1.000

regress each independent variable on all of the other independent variables. If any of the coefficients of multiple determination (R^2) from these equations approach 1.0, there is high multicollinearity.

The analysis was performed, with results as displayed in Table C4. The coefficients of multiple determination for community, bachelor, and family housing buildings exceed 0.85 and provide evidence that high multicollinearity is detectable.

An appropriate strategy for correcting the effects of high multicollinearity is to combine those independent variables that are highly intercorrelated into a single indicator. Conceptually, it was proposed that building sectors could be grouped to form new independent variables to represent sectors of water use. However, it remains to be determined which variables should be grouped accordingly. Factor analysis assumes that observed variables are linear combinations of some underlying factor which, in this case, is construed to be identifiable water use sectors. The following section discusses factor analysis application and how it was adopted in developing the water use model.

Grouping Building Categories: Method of Analysis

The grouping of building variables into logical sectors requires all building categories to be included in the final sector constructs. Concurrently, the new sector variables must also reduce the previously demonstrated high multicollinearity. Because all building categories are in identical units of measure, they can be summed to equate to the total sector building area. Factor analysis can help define the sectors responsible for the covariation among the observed variables, but the data may not lend itself to a clear allocation of all categories to common factors and may require adjustments that are sensible and prudent.

The building category data were therefore subjected to principal factoring with interations and varimax rotation to yield the factor pattern shown in Table C5. The coefficients in the table represent both regression weights and correlation coefficients. The eigenstructure of the correlation matrix is represented by four constructs which jointly explain 77.7 percent of variance in the data.

The first factor is highly correlated with bachelor, family, community, and training building areas which may be taken to represent the installation's community profile. The second factor shows "other" buildings--a very weak predictor of average daily water use--as having the strongest correlation. A military activity variable--storage buildings--displays the strongest correlation with the third factor. The fourth factor is best represented by RD&T buildings. Water use represented by this variable is characterized by research and test processes which may require large quantities of water.

Table C4

Regression Assessment for High Multicollinearity

Variable Name	Symbol	Multiple R^2*
Family housing	FAMBLD	0.860
Bachelor housing	BACBLD	0.868
Training buildings	TRABLD	0.658
Community buildings	COMBLD	0.913
Medical buildings	MEDBLD	0.478
Operations buildings area	OPSBLD	0.425
Maintenance and production buildings	MNTBLD	0.682
Storage buildings	STOBLD	0.362
Research, development, and test buildings	RDTBLD	0.388
Utility plants	UTPBLD	0.631
Administration buildings	ADMBLD	0.425
Other buildings	OTHBLD	0.386
Average moisture deficit factor	MDEFICIT	0.592

*Coefficients of multiple determination (R^2) obtained by regressing each independent variable on all of the others.

Table C5

Results of Varimax Rotated Principal Factor Solution

Variable	Factor Pattern I	II	III	IV
TRABLD	0.743	0.211	-0.099	0.121
MNTBLD	0.610	0.036	0.647	0.007
RDTBLD	-0.079	0.014	-0.023	0.672
MEDBLD	0.413	0.551	-0.045	0.078
ADMBLD	0.511	0.160	0.011	0.428
BACBLD	0.936	0.160	0.054	-0.117
COMBLD	0.921	0.260	0.044	0.115
FAMBLD	0.900	0.104	0.068	0.051
OPSBLD	0.484	-0.030	0.445	-0.048
UTPBLD	0.541	0.171	0.267	0.551
OTHBLD	0.080	0.850	-0.089	0.058
STOBLD	-0.178	-0.115	0.647	0.050
Eigenvalue	5.296	1.690	1.354	0.978
Cumulative % of variance	44.1	58.2	69.5	77.7

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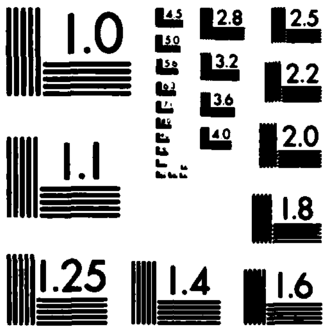

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Four potential water use sectors were identified which consisted of either single building category variables (other, storage, and research) or multiple building categories, which were combined by adding gross floor areas to form a new composite variable. Five building category variables--maintenance, operation, medical, administration, and utility plants--could not be assigned to these four sectors based on the factor analyses. Additional statistical analyses and criteria were established to determine the most appropriate sector to which each of these five variables should be allocated.

The first step was to regress average daily water use on the four variables representing the four water use sectors. The moisture deficit variable was also included as an independent variable. The results of the regression are shown in the following equation. The t-statistic is shown in parentheses for each corresponding coefficient:

$$
\begin{aligned}
Q_{ao} = \underset{(0.132)}{23.637} + \underset{(12.076)}{.406}\ \text{SECTOR 1} - \underset{(-0.876)}{0.877}\ \text{SECTOR 2} \\
+ \underset{(1.700)}{0.113}\ \text{SECTOR 3} + \underset{(5.490)}{1.641}\ \text{SECTOR 4} - \underset{(-0.672)}{.002}\ \text{MDEFICIT}
\end{aligned}
\qquad \text{[Eq C1]}
$$

$R^2 = 0.783$ F = 60.656

SEE = 997.2 D.F. = 5 and 84

where:

SECTOR 1 = composite variable of the summed total gross floor area of family, bachelor, training, and community buildings

SECTOR 2 = other building gross floor area

SECTOR 3 = supply building gross floor area

SECTOR 4 = research building gross floor area.

Each of the remaining five building categories was subjected separately to a series of regression analyses in which their corresponding floor areas were added one at a time to each sector. For example, the gross floor area of the maintenance category was added to SECTOR 1, then to SECTOR 2 through SECTOR 4, with a regression analysis performed for each successive assignment. The change in R^2 was observed at each step, and the building category was finally assigned to the sector that produced the highest multiple R^2 value during the regression analyses. At no time during this entire procedure did the R^2 value change more than 0.02. Also, no building category was assigned to SECTOR 2 based on the R^2 criteria, and the t-value for its coefficient remained insignificant in every regression procedure. This outcome was expected because the category of "other" buildings, representing this sector, does not contribute meaningfully to explaining the variance of average daily water use.

Therefore, it was decided to analyze R^2 change in the model when this variable was added to the gross floor area of each of the three remaining sectors. The result of the series of regressions was to assign "other" buildings to SECTOR 1.

As a result of these analyses, all building categories were assigned and represented by three distinct water use sectors, which are summarized in Table C6. Three identifiable sectors emerge as distinct independent variables: a community service and support sector (COMMON), a military activities sector (MILACT), and a research and post utility support sector (RDTUTIL). The numerical values for the building areas in each factor were summed to form three new variables with labels as shown in the table. The next section describes the data characteristics of these variables and the retests for high multicollinearity. These new variables are appropriately referred to as water use sectors.

When research buildings were combined with utility plants, the bivariate regression slope of 1.581 was significant below the 0.01 level (Table C7). The effect of grouping maintenance, storage, and operations buildings is to reduce the influence of outliers previously noted in the scattergram analysis of storage buildings with average day water use. As expected, the sign of the bivariate regression slope for this sector is positive, although significant at the 0.16 level. Outlier influence still exists, but removal is not warranted until the full model is tested using multivariate regression analysis, and residuals are examined. The community sector variable is strongly correlated with average daily water use and accounts for .84 of the variance of the dependent variable alone. Regression techniques were again used to check for the reduction of high multicollinearity observed previously when the individual building categories were assessed separately. The R^2 values for each sector and the moisture deficit factor are: COMMUN (0.452); MILACT (0.118); RDTUTIL (0.008); and MDEFICIT (.500). The problem of high multicollinearity is no longer present and the variables are acceptable for evaluation in the water use model.

Final Model Specification

Having determined three sectors of water use activities, these newly formed independent variables can be entered into the following linear additive model:

$$Q_{ad} = a + b_1 \text{ (COMMUN)} + b_2 \text{ (MILACT)} + b_3 \text{ (RDTUTIL)} + b_4 \text{ (MDEFICIT)} + e \quad \text{[Eq C2]}$$

where: Q_{ad} = average daily installation water use in k-gal

$b_1 \ldots b_4$ = coefficients of the corresponding independent sector variables

Table C6

Index of Grouped Building Category Variables

Factor No.	Grouped Building Categories		New Independent Variables	Description
1	FAMBLD BACBLD TRABLD COMBLD MEDBLD ADMBLD OTHBLD	to form	COMMUN	Community serivce and support sector
2	OPSBLD MNTBLD STOBLD	to form	MILACT	Military activities sector
3	RDTBLD UTPBLD	to form	RDTUTIL	Research and post utility support sector

Table C7

Sector Variable Characteristics*

Variable Code	High Value	Low Value	Mean	Standard Deviation	Correlation Coefficient**	Correlation Significance	Bivariate Regression Slope	Slope Significance***
COMMUN	19095	80	4406	5089	.843	.0001	.344	.0001
MILACT	8787	51	2141	1988	.150	.0789	.157	.1578
RDTUTIL	2607	0	194	376	.286	.0031	1.581	.0063

*Values are for 90 cases.
**Pearson's r for paired variables consisting of Q_{ad} and the given sector variable.
***Significance determined by two-tailed t-test.

COMMUN = community service and support sector in k-sq ft

MILACT = military activity sector in k-sq ft

RDTUTIL = research and post utility support sector in k-sq ft

MDEFICIT = moisture deficit factor (as defined in the conceptualized model)

a = constant term

e = error term.

The expected signs of the variables are all positive.

The water use function was estimated from data on all 90 installations, and the full model result was:

$$Q_{ad} = \underset{(-0.90)}{-1.65.05} + \underset{(12.29)}{0.34}\ \text{COMMUN} + \underset{(1.85)}{0.10}\ \text{MILACT} + \underset{(4.99)}{1.40}\ \text{RDTUTIL} - \underset{(-0.21)}{0.005}\ \text{MDEFICIT}$$

The t-statistic is given in parentheses below each estimated parameter. For 90 installations, the two-tailed critical value at the 95 percent level is 1.98; this leaves in doubt the significance of the moisture deficit factor, which also exhibits the opposite expected sign. The constant value is also negative in sign and significant at the 0.369 level. The variance explained by the regression equation was measured by the R^2 statistic and was 0.784. The F-statistic was 77.10, with 4 and 85 degrees of freedom and significant at the .0001 level. The standard error of estimate or average error in predicting average daily water use from the regression equation was 989 k-gal. An analysis of the residuals scatterplot showed no apparent trend or pattern that would violate the assumptions of regression analysis; however, an extreme outlier was observed, which had a standardized residual value of 6.10, contrasted to the next worst outlier, which had a value of 3.78. This point represented Redstone Arsenal, and its presence may have biased the estimates of the parameter coefficients. To determine the influence of this outlier, the case was removed from the data set, and the model was again subjected to regression analysis. The results were:

$$Q_{ad} = \underset{(-0.50)}{63.71} + \underset{(16.90)}{0.33}\ \text{COMMUN} + \underset{(1.76)}{0.07}\ \text{MILACT} + \underset{(3.56)}{0.74}\ \text{RDTUTIL} + \underset{(0.68)}{0.0001}\ \text{MDEFICIT}$$

The response to the removal of the single outlier is clearly seen in the reduction of the parameter coefficient for the research and post utility support sector variable. This outlier had caused an upward bias in this coefficient. The effect on the other coefficients was slight except for the moisture deficit factor which now reflects the expected positive sign. The multiple R^2 value is now increased by nearly 12 percent to 0.874. The standard error of the estimate was reduced to 693 k-gal, which suggests that prediction error is more than 1.5 times as great in the outlier equation. Also, the F-value was enhanced to 145.79 with 4 and 84 degrees of freedom and remained highly significant below the .0001 level.

Additional extreme outlier removal did not result in a significant change in the coefficient of multiple determination and the parameter coefficients remained stable. Therefore, all other cases were retained for computation of the best fit model. The moisture deficit factor, significant at the 0.496 level, does not contribute to the explanation of average daily water use, but may offer an improved predictive capability if summer seasonal water use data were available for analysis as the dependent variable.

Stepwise regression with forward selection of predictor variables was used to calibrate the model. Regressions that used the logarithms of the variables were also tested, but these equations did not provide higher coefficients of multiple determination. Fitting the combined 89 installations yielded an equation of best fit as follows:

$$Q_{ad} = \underset{(23.53)}{0.339\ \mathrm{COMMUN}} + \underset{(2.13)}{0.079\ \mathrm{MILACT}} + \underset{(3.66)}{0.754\ \mathrm{RDTBLD}} \qquad \text{[Eq C3]}$$

The t-values are shown in parentheses, and all were found to be significant at the 0.05 level. The constant term has been deleted from the equation because it was not significantly different from zero. The value of the constant term was -73.16 with a corresponding t-value of -0.575. The R^2 is 0.873 with an F-value of 195.45, significant below the .0001 level. The standard error of the estimate was 690 k-gal.

Community service and support sector is by far the most important predictor variable and alone accounts for .846 of the variance of the dependent variable in the best fit equation (Table C8). The military activity sector and the research and post utility support variable are statistically significant, but their effect is very small compared to the community service and support sector. They do provide a genuine explanation of a portion of the water use variance; however, their relative importance should be recognized and understood.

Table C8

Regression Equations: Summary of Empirical Results

Regression Equation (standardized coefficients and t-statistics given in parentheses above and below, respectively).	Selected Statistics R^2	SEE	F	N
Theoretical Equation:				
$Q_{ad} = a + b_1\,(\text{COMMUN}) + b_2\,(\text{MILACT}) + b_3\,(\text{RDTUTIL}) + b_4\,(\text{MDEFICIT}) + e$				
Intermediate Equations:				
(.837) (.099) (.252) (-.014)				
$Q_{ad} = -165.05 + 0.34$ COMMUN + 0.10 MILACT + 1.40 RDTUTIL - 0.0005 MDEFICIT	.784	989	77.1	90
(-.90) (12.29) (1.85) (4.99) (-0.21)				
(.886) (0.73) (.139) (.038)				
$Q_{ad} = -63.71 + 0.33$ COMMUN + 0.07 MILACT + 0.74 RDTUTIL + 0.0001 MDEFICIT	.874	693	145.8	89
(-.50) (16.90) (1.76) (3.56) (0.68)				
Best Fit Equation:				
(.910) (.082) (.141)				
$Q_{ad} = 0.339$ COMMUN + 0.079 MILACT + 0.754 RDTUTIL	.873	690	195.4	89
(23.53) (2.13) (3.66)				

APPENDIX D:

COMPARISON OF ESTIMATION RESULTS BY INSTALLATION

The following presents the reported actual values for average daily water service (Q_{Actual}) obtained by dividing entries of total annual water service (FY 1981 Redbook) by 365 days. Estimated values (Q_{Est}) are shown for average daily water service computed by applying both current Army procedures (Chapter 4) and the water requirement model developed in Chapter 5. Residuals are displayed for both techniques.

Installation	FY 81 Redbook	Current Procedures		Water Requirement Model	
	Q_{Actual}	Q_{Est}	Residual	Q_{Est}	Residual
Fort Bragg	6477	6437	40	6891	-414
Fort Campbell	4991	6515	-1524	4919	73
Fort Carson	3321	6254	-2933	3153	167
Fort Devens	1575	4661	-3086	3104	-1530
Fort Drum	447	945	-498	1633	-1216
Fort Hood	7959	9960	-2001	6813	1146
Fort Indiantown Gap	642	1252	-610	1769	-1127
Fort Sam Houston	3790	4203	-413	3099	690
Fort Lawton	65	33	32	145	-81
Fort Lewis	7288	6576	712	5954	1334
Fort McCoy	596	5861	-5265	2461	-1865
Fort McPherson	1025	2214	-1189	1791	-766
Fort Meade	3135	6893	-3758	3374	-239
Fort Riley	4134	5927	-1793	4436	-302
Fort Sheridan	645	1390	-745	1374	-729
Fort Stewart	3412	6511	-3099	3441	-30
Fort Irwin	1031	1179	-148	655	376
Presidio of San Francisco	3584	2779	805	2584	1000
Vancouver Barracks	135	12	123	191	-55
Yakima Firing Range	473	73	400	191	283
Fort Ord	6135	6213	-78	5450	685
Fort Polk	3796	5508	-1712	4166	-370
Fort Belvoir	1805	3077	-1272	3186	-1380
Fort Benning	6774	6552	222	6176	598
Fort Bliss	5982	6389	-407	5107	875
Fort Chaffee	693	1579	-886	1228	-535
Fort Dix	2901	4361	-1460	3266	-365
Fort Eustis	2857	2423	434	2034	823
Fort Gordon	2258	4375	-2117	2927	-669
Fort A. P. Hill	97	276	-179	501	-404
Fort Jackson	4567	4204	363	3312	1255
Fort Knox	5090	6635	-1545	6286	-1196
Fort Leavenworth	2055	2070	-15	2144	-90
Fort Benjamin Harrison	552	2656	-2104	1554	-1001
Fort Lee	1655	2878	-1223	2335	-679
Fort McClellan	1507	3308	-1801	1881	-373
Fort Monroe	1510	729	781	613	897
Fort Hamilton	449	2431	-1982	989	-540
Fort Pickett	720	517	203	810	-90
Fort Rucker	2488	3887	-1399	2306	182
Fort Sill	3049	4767	-1718	4117	-1068
Fort Leonard Wood	4010	4799	-789	3932	79
Carlisle Barracks	607	543	64	488	119
Fort Huachuca	2680	2820	-40	2365	315
Fort Ritchie	439	1269	-830	581	-142
Anniston Army Depot	1262	1072	190	756	506
Army Materials and Mechanics Research Center	65	165	-100	380	-315
Harry Diamond Laboratories	88	311	-223	456	-367
Letterkenny Army Depot	566	1254	-688	711	-151
Lexington Blue-Grass AD	247	431	-184	542	-294
McAlester AAP	568	243	325	888	-319
Navajo Depot Activity	82	55	27	299	-216

Installation	FY 81 Redbook Q_{Actual}	Current Procedures Q_{Est}	Current Procedures Residual	Water Requirement Model Q_{Est}	Water Requirement Model Residual
New Cumberland Army Depot	342	1509	-1167	661	-319
Picatinny Arsenal	2544	1230	1314	1532	1013
Pine Bluff Arsenal	863	312	551	321	543
Pueblo Depot Activity	241	203	38	560	-319
Red River Army Depot	1404	1305	99	747	656
Redstone Arsenal	9847	(Outlier)		(Outlier)	
Rock Island Arsenal	1323	1629	-306	992	332
Rocky Mountain Arsenal	188	86	102	250	-62
Sacramento Army Depot	502	666	-164	345	157
Savanna Army Depot	219	146	73	405	-186
Seneca Army Depot	252	380	-128	518	-265
Sharpe Army Depot	225	366	-141	317	-92
Sierra Army Depot	1123	347	776	537	586
Tobyhanna Army Depot	388	936	-548	499	-111
Tooele Army Depot	30	962	-932	742	-711
Umatilla Depot Activities	167	73	94	259	-92
Fort Wingate Depot Activity	12	44	-32	108	-96
Watervliet Arsenal	317	652	-335	428	-110
Corpus Christie Army Depot	717	714	3	216	501
Detroit Arsenal	495	1270	-775	550	-55
Fort Monmouth	764	2050	-1286	1933	-1168
Jefferson Proving Ground	47	106	-59	160	-113
St. Louis Area Support Center	179	226	-47	329	-150
Aberdeen Proving Ground	3848	5501	-1653	4203	-355
Dugway Proving Ground	1188	602	586	640	548
Natick Development Center	2827	365	2462	527	2300
White Sands Missile Range	1947	1748	199	2392	-455
Yuma Proving Ground	900	648	252	507	393
Fort Detrick	1594	931	663	694	900
Fitzsimons Army Medical Center	850	1001	-151	863	-13
Walter Reed Army Medical Center	1300	1814	-514	2257	-956
Arlington Hall Station	157	632	-475	296	-139
Vint Hill Farms	232	465	-233	357	-126
Bayonne Military Ocean Terminal	417	682	-265	787	-370
Gulf Outport	17	54	-37	89	-72
Oakland Army Base	326	637	-311	481	-154
Sunny Point Military Ocean Terminal	101	70	31	31	70
United States Military Academy	2975	2709	266	3476	-502

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